THE OCEAN

SECTION II.

J. D. M. Beglar.

THE

OCEAN, ATMOSPHERE AND LIFE

Being the Second Series of

A DESCRIPTIVE HISTORY OF THE

PHENOMENA OF THE LIFE OF THE GLOBE

442 R.R.2

By ELISÉE RECLUS

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SECTION II.

THE OCEAN;

THE ATMOSPHERE, METEORS, AND LIFE.

PART II.—THE ATMOSPHERE AND METEOROLOGY.

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CHAPTER XIII.

THE VAPOUR OF WATER.—THE MOISTURE OF THE AIR.—ABSOLUTE MOISTURE AND RELATIVE MOISTURE.

The air which moves and is mingled incessantly at the surface of the earth in breezes or in tempests, in whirlwinds or in cyclones, is at the same time the great agent for distributing the vapour of water. Owing to the movement of exchange which is established from one pole to the other between all the regions of the atmosphere, the water which evaporates from oceans, rivers, and inland lakes, distributes itself over all the countries of the globe, and even over the deserts. While the liquid sea washes only parts of the land, a second sea borne by the atmosphere floats often invisibly over the circumference of the planet.

Above every sheet of water, and even above ice, vapour is always formed, provided that the air be not already saturated; that is to say, that it does not contain exactly the quantity with which it may be mixed without there being a precipitation of moisture. This limit of saturation varies with the temperature. At 4 degrees Fahr. below zero, a cubic yard of air can hardly contain more than 15 grains Troy of vapour; at the temperature of melting ice it cannot receive more than 7 grains of moisture; from 50 to 86 degrees Fahr. the number of grains that it absorbs corresponds nearly to the divi-

sions of the thermometric scale; but above 80 degrees the capacity of air for the vapour of water increases in a much more rapid manner. At 212 degrees Fahr. the atmosphere can absorb its own bulk, the tension of water becomes equal to that of air, and the phenomenon of ebullition is produced; that is to say, the vapour in formation counterbalances all the atmospheric column situated above.

The vapour increases in the atmosphere in proportion to the increase of temperature; such is the true meaning of the vulgar adage which attributes to the sun the power of "pumping up the waters of the sea" to form clouds. Still the same increase of atmospheric heat over two sheets of water of equal temperature does not necessarily produce the same quantity of vapour; the agitation of the air is also one of the most important elements in assisting evaporation. In short, let the atmosphere be perfectly tranquil, and the portion which reposes above the waters will be soon saturated with moisture, and will not be able to absorb any more; but let the aerial bed already charged with vapour be carried away by the wind, and replaced by a new stratum of dry air, this will likewise take its share of humidity, then those which follow will be saturated in their turn, and the phenomenon of evaporation will advance the more rapidly, the more violent the current of air itself is. We know with what speed the dry winds harden the fields and wet roads; one would say that they lick the ground, so rapidly do all the pools of water disappear.

After having thus facilitated evaporation on the sheets of water and moist parts of the continents, the winds transport vapour into the various countries of the earth, and mingle it with dry air, so that nowhere, even at thousands of miles from the ocean, is the air completely destitute of moisture. However, we easily understand that the quantity of vapour is not at equal temperatures distributed in a uniform manner. In open sea the atmosphere is always very near the point of saturation even when the clouds do not threaten to discharge rain, and consequently the vapour contained in the sea atmosphere diminishes pretty regularly from the equator towards the poles, following the isothermal curves.* On the shores bathed by the moist air of the oceans, the proportion of watery vapour diminishes likewise in a normal manner on both sides of the equator. But in the interior of the continents, where the distribution of lakes, rivers, and mountains presents such a great variety, and where the winds follow such different paths, the atmospheric vapour is also dis-

* See below, the section entitled, *Climates*.

tributed very unequally. While the air is almost always either saturated with vapour, or very near the point of saturation, above England and Ireland, in the steppes of Central Asia it is of an extreme dryness, and usually it contains only from 15 to 20 per cent. of the vapour which it could absorb. On an average the atmosphere of the continents contains three-fifths of the moisture which it would hold if it were completely saturated in all its extent.* This proportion is that which the surface of oceans or basins of evaporation, compared to that of the dry land, would have led us to suppose beforehand.

When the atmosphere contains all the moisture which its temperature can bear, the least particle of supplementary vapour is sufficient to determine the precipitation under the form of drops of a part of the vapourized water; either a mist or cloud is produced, and it begins to rain. Inasmuch as the point of saturation varies in every country and at every season according to the oscillations of heat and cold, it follows that the same quantity of water contained in the atmosphere does not determine the formation of rain at two different temperatures. The same proportion of moisture which, during the winter, completely saturates the cold air, and falls in snow to the ground again, would be very small in the heated atmosphere of summer, and the aerial mass that should contain it would leave an impression of dryness; in the same way a wind, such as the scirocco, for example, would be dry in a warm country like Barbary, and become moist on the cold mountains of the Alps.† It is, therefore, important to distinguish clearly between absolute moisture and relative moisture. The first may increase gradually, while the second diminishes; and though the air then would contain an increasingly greater proportion of atmospheric vapour, it would not the less appear little by little to become drier.

This is, indeed, what takes place every day, as is proved by the long observations of the meteorologist Kämtz. In the morning towards sunrise the temperature of the atmosphere is at its lowest, and it is precisely then or a little later, because of the vapours from the sun, that the air approaches the point of saturation. In proportion as the heat and absolute moisture increase, the relative moisture diminishes, and then rises again when the sun sinks towards the horizon, and the temperature falls. Such is the contrast observed in a normal manner in the temperate countries of Western Europe. When the opposite phenomenon presents itself, the cause is due to some great atmospheric disturbance, but the regular oscillations of moisture do not fail to re-establish themselves. The only regions where the air approaches

* Saigey, *Petite Physique du Globe*.

† See above, p. 263.

the point of saturation in the warmest hours of the day, are the high peaks towards which the vapours of the plain rise. Thus, while at Zurich, at the foot of the mountains, the relative moisture is, on an average, much less in the afternoon than in the morning, the exactly

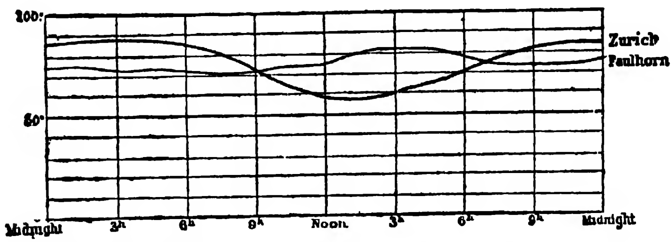


Fig. 124 —Variations in the Hygrometric degrees at Zurich and Faulhorn.

contrary phenomenon occurs on the Faulhorn, whose high peak is often enveloped in clouds.

During the various seasons of the year, the sucessive variations of which reproduce on a larger scale the progress of the day, the absolute moisture and relative moisture present the same contrast as at the corresponding periods of the day; in proportion as the heat increases and the quantity of watery vapour becomes greater, the air retreats from the point of saturation, and seems in consequence to become dryer and dryer. This is shown by the accompanying figure borrowed

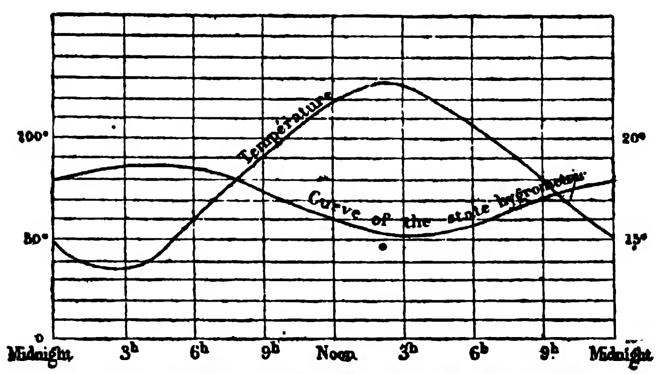


Fig. 125.—Comparative states of the Thermometer and Hygrometer at Halle in July.

from a work by Kamtz. Still it is necessary to remember that these

curves represent only averages, and that in reality the oscillations of the atmospheric vapour are much more complicated. In fact, every variation of temperature, every change of wind, modifies, either by slow gradations or by abrupt shocks, the condition of the air with respect to watery vapour; dryness, moisture, and saturation succeed each other rapidly. Sometimes in a single day one can count a dozen showers and clearings up of the weather. The curves which should then represent the hygrometric state of the atmosphere would be very complicated.

CHAPTER XIV.

FORMATION OF MISTS AND CLOUDS.—HEIGHT, THICKNESS, FORM, AND ASPECT OF CLOUDS.

WHEN a mass of air resting on the ground becomes super-saturated with moisture, a certain portion of the vapour is immediately condensed in whitish drops, which by their multitude completely veil or hide all objects, and only allow a dim light to pass through; these innumerable drops constitute mists. They are clouds still attached to the earth and creeping along the plains or up the slopes of mountains. They are formed more especially in the night because of the chilliness of the atmosphere; often we see them rise in the evening from marshy surfaces and damp meadows. When a cold wind descends from the heights of the air, and retains moisture in its lower strata, the mist becomes permanent, and may last for days and even whole weeks. Frequently the sky is pure at a slight elevation above these vapours, and from the top of a summit which rises into free air we may then contemplate at our feet a great white sea, whence the hills spring up here and there like islands.

The clouds properly so called are mists, which, instead of remaining attached to the ground, float suspended in the atmosphere at various heights above the earth. Whence comes it that the vapours imparted to the atmosphere by the surface of the waters mount thus into space? Such is the question which presents itself naturally to all inquiring minds, and which has formed the subject of many mythological fables. The discoveries of modern natural philosophy have resolved this great problem in a general manner. It only remains now to elucidate certain secondary points.

In consequence of the gradual decrease of temperature which the *superposed* aerial strata generally experience on leaving the surface of the ground, the weight of the vapour in the atmosphere is much less in the higher regions than below. It results from this, that the expansive power of the moisture contained in the lower stratum of air is not balanced by the pressure of all the particles lying above it.

The vapour from below rises, therefore, to the upper spaces, as a cork to the surface of the sea, till it has at last penetrated into a colder region of air, where it finds itself at its point of saturation,* and is condensed in drops.* Every cloud that we see in the sky is, therefore, according to Tyndall's expression, only the visible summit of an ascending column of vapour rising into the transparent atmosphere.

The condensed particles of vapour are at first extremely fine; but the air is never in repose, and the drops carried to the right or left by partial currents meet and unite in larger globules. On an average, as the measures taken by Kämtz confirm, the diameter of the first liquid particles is so small that no less than from 25 to 30 are needed to make ·04 of an inch of thickness. But hundreds and thousands of them driven one against the other unite in smaller or larger drops, and when the drops at last reach the ground they are not less than a ·02 of an inch in size, or even more. While they are still as fine and even lighter than dust, they are the playthings of the aerial currents, which toss them, take them up as they fall, and carry them far away. Clouds of vapour are carried through space as the heavier eddies of sand from the plains very often are. Then when the drops, constantly growing larger by the union of the particles dashed against each other, have become too heavy to allow themselves to be carried along like dust, they fall obliquely to the ground. According to the temperature, the force of the winds, and thickness of the clouds, they are either fine rains, showers, or real deluges.

Even when the atmosphere seems to be perfectly calm and no wind is blowing, it often happens that the clouds do not the less remain at a great height, as if they were lighter than the surrounding air. This is because an alternate and continued play of condensation and evaporation is then occurring in the thickness of the clouds and invisible vapours. The drops of rain already formed really fall from the cloud, but in the lower strata not yet saturated they are vapourized again; then mounting a second time towards the colder cloud, they are again condensed there, and in consequence their movement of descent recommences. A perpetual coming and going of particles of vapour visible during their fall, and invisible during their ascent, is thus established on the lower surface of the cloud, which itself changes in dimensions and form, according to the least variations of the temperature. If the heat increases, the cloud will be gradually decreased; if the air become a little colder, the haze of drops will increase in volume. There are few sights which exceed in beauty that

* Saigey, *Petite Physique du Globe.*

which is presented by a fine calm summer's afternoon with clouds alternately formed and dissolved in the azure of the sky. We first see a simple flake of vapour similar to a white bird floating in space; but this flake grows, spreads, and is surrounded by undecided streamers; it is now a cloud still semi-transparent, allowing us to see the blue of the air through its rifts; then it is a real cloud developing its folds over the arch of the heavens. But let us look a few instants afterwards, and already the cloud is destroyed, perhaps it has divided into numerous fragments which become smaller and smaller, are torn, scattered, melt, and disappear; we think we see them still, but it is an illusion for the sky has resumed its blue. At other times, on the contrary, the first cloud that we have seen rise does not remain isolated; new masses of vapour are condensed around it, and the space is gradually filled with floating clouds, which approach one another, join, and agglomerate; and soon the sky, which seemed entirely free from vapour, presents in every part a thick stratum of clouds formed on the spot by the chilling of the atmosphere, and the condensation of the particles of moisture.

The height at which the clouds are formed and sustained varies in every season and country, according to the temperature and direction of the winds. There are some, especially among the clouds chased by tempests, which touch the tops of buildings or trees; others float at many hundred yards of elevation; others, again, are level with the highest points of mountains, and all the aeronauts who have passed the summits of the great peaks in their ascents, have seen strata of cloud far above their heads. M. Liais estimated a height of 7¼ miles for the most elevated mass of vapours, the dimensions of which he took astronomically. This is an altitude exceeding by nearly two miles that of the highest mountain of the earth, and undoubtedly many clouds mount much higher still in the upper strata of the atmosphere. As to the mean elevation of the zone where the vapours are condensed, it seems to vary in the countries of Western Europe between 1¼ and 2 miles; it would therefore exceed the Vosges and mountains of Auvergne, and would only be overtopped by the ridge of the Pyrenees and the peaks of the Alps. Besides, this zone is necessarily variable because of the changes of temperature: it is higher in summer, and lower in winter.

As to the thickness of the strata of clouds, it is no less various than the height at which the vapours are condensed. There exist clouds of all vertical dimensions from the thin, transparent veil which allows the light of the stars to pass through, to those enormous masses, super-

posed in strata 3 miles in thickness, like those that Barral and Bixio traversed in 1850. M. Peytier has found, by 48 measurements taken in the Pyrenees, that the thickness of the cloudy strata was on an average from 490 to 550 yards. According to Piazzi Smyth, this thickness is ordinarily 330 yards round the Island of Teneriffe, where the meteorological phenomena generally present great regularity. Besides, it frequently happens that several layers of clouds mount one above another in the heights of the sky, and the total thickness of the masses of condensed vapour over one point of the earth is thus much augmented. These superposed strata of clouds are are often due to the aerial currents and counter-currents which blow in opposite directions at various heights. But often, too, when the air is perfectly calm, we see some of these cloudy layers divided vertically in the atmosphere. This is because the lowest stratum, once formed, constitutes for the upper spaces a sort of sea the moisture of which evaporates under the rays of the sun, like that of the ocean or lakes situated below. The moisture changed thus into invisible vapours condenses in the colder air at a certain height, and forms a second stratum of clouds, which in its turn originates a third and more elevated layer.*

In consequence of the different causes which give rise to vapours, the clouds assume the most varied appearances over the land, the sea, and even the rivers. It is said that the red men, those sagacious observers of all the phenomena of nature, knew, whilst they yet ranged the central plains of North America, how to recognize from afar the course of the Mississippi by the form of the clouds stretching above the river in elongated strata. Still it is principally round the

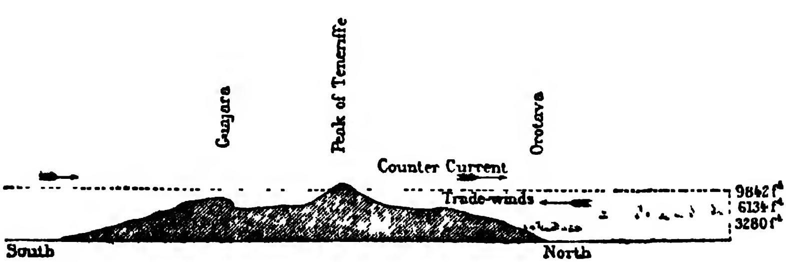


Fig. 126.—Winds and Clouds at Teneriffe.

outline of the islands of the ocean that we can best observe this difference between terrestrial and maritime clouds. At Teneriffe the con-

* Saigey, *Petite Physique du Globe.*

trast occurs in the most striking manner. In summer the great white sheet of clouds which the trade-winds carry along, is developed uniformly over all the oceanic spaces. But in calm weather this bed of clouds terminates at a certain distance from the opposite flanks of the peak of Teyde, in a kind of escarpment from 600 to 900 feet high. Within this circle formed by the oceanic clouds the land is surrounded by its own zone of steaming vapours; these latter, much lower than the larger clouds of the sea, attach themselves to the slopes in long fringes, moved in a very different way from that of the exterior zone, and quite distinct by the colour and form of their folds. Piazzi Smyth, who was able thoroughly to study the phenomena of these various strata for many months, compares the terrestrial clouds of Teneriffe to that of land-ice which is formed around the islands and polar continents, and which constitute a solid platform, while the ice-fields in the open sea are broken by the currents, and carried away in fragments.

Meteorologists have attempted to class the clouds in various categories according to their exterior appearance, but this is a very difficult undertaking, because of the infinite variety of forms, and the extreme mobility of the vapours which float in the sky. However, they have generally adopted Howard's classification, according to which the clouds are referred to three great types, the *cirrus,* the *cumulus,* and the *stratus,* which mingle variously with each other, and thus produce secondary combinations bearing the names of *cirro-cumulus, cirro-stratus,* and *cumulo-stratus.* These are, however, for the most part conventional divisions, which every meteorologist can modify at his pleasure, and Fitzroy has added ten varieties to the types and sub-types of clouds indicated by Howard.

The cirri are small white clouds, as fine as carded wool or plumes of feathers; these are the *cats-tails* of sailors, and are always perceived at a great height in the sky. According to Kämtz, their mean altitude is not less than 4 miles above the highest mountains and most elevated spaces to which aeronauts have attained. These slender cloudy filaments are still found, most often arranged in parallel rows, in the same direction as the trade-winds or counter trade-winds, which indicates the regularity of the aerial currents in the heights of the atmosphere. The cirri are formed of icy particles, as natural philosophers have been able to ascertain by the luminous phenomena of reflection and refraction which occur in them. When the cirrus sinks and the crystals of ice are melted, the cloud gradually undergoes a modification of appearance, and changes into the cirro-stratus

or cirro-cumulus. In the first case, its light whirls are mixed and confused in a cottony and greyish mass, prognostic of approaching rain; in the second the sky is filled with those little dappled clouds, which by contrast give to the blue of the air such a beautiful hue. According to popular legends, these are flocks of sheep grazing in aerial spaces.

The cumulus which seamen distinguish under the name of "cotton bale" is distinguished from the cirrus by its origin no less than by its aspect. Instead of having been brought from very distant regions by the wind, it has generally been formed on the spot by the condensation of ascending columns of vapour. We see this sort of cloud piled on the edge of the horizon, in enormous rolls with clearly defined outlines; one might sometimes think them to be gigantic chains of mountains, whose rounded white summits stand out against the deep azure. Their base is almost always horizontal, and spreads widely in an immense layer, indicating the precise zone of space where the invisible vapours coming from below are condensed into mist. The heavy cumulus, charged with an enormous weight of moisture, never rises to the same height as the cirrus, and hardly exceeds two miles in elevation; the highest which M. Liais measured was at 2 miles. It mingles variously either with the cirrus or stratus; that is to say, with those bands of clouds disposed in the sky in long sweeps or parallel strata. This form is what the mists most frequently affect on detaching themselves from the ground, but it must be said, also, that clouds in reality most distinct resemble "stratus" when they are seen in perspective on the distant horizon. As to the "nimbus" of which some meteorologists have wished to make a special type, it is simply a rain-cloud which is developed in the sky and breaks into showers.

By the marvellous diversity of their forms, clouds are one of the great beauties of the atmosphere. Among all the images, whether fearful or graceful, that the fancy of man can dream of, there is not one which is not to be found in the vapours of space. By their fugitive outlines clouds resemble flights of birds, eagles with outstretched wings, groups of animals, reclining giants, and monsters like those of fable. Other clouds are chains of mountains with snowy summits; others, again, represent immense cities with gilded cupolas. Poets see in these groups distant archipelagos, where the happiness so much sought for, and which does not exist on this earth, is to be found. Superstitious people, often pursued by the terror of their own crimes, see in them bundles of weapons, war-horses, armies in battle-array,

and massacres. The light playing in this fantastic world of images increases still more their astonishing variety; all imaginable shades shine over these floating bodies from snowy whiteness to fiery red; the sun colours them successively with all the graduated tints of dawn, daylight, and sunset; meadows and forests are reflected there in greenish tones, and the sea itself is reproduced vaguely by a colour of metallic brilliancy recalling that of copper or steel.

CHAPTER XV.

INFLUENCE OF THE WINDS ON THE FORMATION OF SNOW AND RAIN.—DISTRIBUTION OF RAIN OVER PLAINS AND MOUNTAINS.

EVERY aerial stratum containing aqueous vapour to the very point of saturation, must necessarily let fall to the ground a certain quantity of drops, which are the cloud itself. If the air were perfectly calm these precipitations of moisture would always occur in a slow and continuous manner; the earth, enveloped in a constant mist, would, however, never be watered by heavy rains. Nevertheless, in almost all the countries of the world clouds and showers follow fine weather, and fine weather succeeds to rain, owing to the winds which meet in space and mingle air and moisture variously together. They purify the atmosphere from the superabundance of its vapours, and determine the formation of those sudden rains, without which the circulation of the waters and the general movement of life would be much less rapid on the surface of the globe. In fact, when two aerial masses unequally heated come in contact with one another and mingle, the temperature of the warmest suddenly sinks; its capacity for holding vapour diminishes in consequence, and the moisture which it contains must be precipitated in rain. It is true that on its side the coldest wind is warmed and saturated by a greater quantity of vapour. But there is no compensation in this, for the point of saturation in the aerial strata is not exactly proportioned to the temperatures. If the two masses mingling assume a mean temperature between the two extremes, on the other hand, the capacity for holding vapour falls relatively below this average. Hence the immediate effect of precipitation which occurs ordinarily at the time of the conflict of the winds, and especially at the mingling of the counter trade-winds, loaded with moisture, and the cold winds coming from the pole. It is then that we see clouds amass themselves so rapidly in the sky and fall suddenly in violent showers. A few hours, sometimes even a few minutes, are sufficient for the blue of the air where the two winds meet to be hidden by the dark folds of storm-clouds.

At the Paris observatory, it has been ascertained that the quantity of rain falling on the terrace of the building at 91 feet high is always less than the quantity of water collected in the courts situated below. This is because, in traversing the atmospheric strata saturated with moisture, each drop enlarges itself on the way by other scattered droplets, and continually brings back to the earth the pluvial moisture which has evaporated. Perhaps, too, we ought to see in this increase of precipitation only a local fact, and attribute it in great part to an eddy of the drops in a kind of funnel formed by the courtyards of the building. At Paris the difference between the respective quantities of rain which fall on the terrace and into the court is about 2·4 inches; at the summit of the edifice the annual depth of rain is 19·7 inches, while at the base this depth rises on an average to 22 inches. At Berlin the respective quantities of pluvial rain which fall on the roof and in the courtyard of the observatory are a little less, but the difference is also about a ninth.

Still we must not conclude from these facts that rains are less abundant on the mountains than in the countries lying at their foot. On the contrary, as the densest clouds always float at a considerable height above the low plains, it results from this that the most abundant rains fall on the slopes of the mountains. Driven by the wind, the moist masses strike against the cold rocks standing up across their route, and turn to rain; the ravines and gorges are filled, while the lightened clouds mount the sides and cross the chain of mountains by the passes opening between the summits. This is a phenomenon which we can easily observe from the height of an advanced promontory, when the rain-clouds roll towards the mountains. Even when the lower plains do not receive a drop of rain the sides of the mountains are inundated and the torrents swell. Arriving in blackish or copper-coloured masses, which one would think were solid as rocks or metal, the clouds disappear in light greyish vapours; long after they have passed a transparent mist may be seen hanging to the bushes and tree-tops. This is the superabundant rain which evaporates.

Among the causes which determine a greater precipitation of moisture on the mountains than on the plains below, we must also reckon the difference of temperature usually existing between the summits and the surrounding atmosphere. During the day the slopes exposed to the warmth of the sun are more heated than the surrounding air, at least in calm weather; but the ravines often remain much colder, and consequently the contact causes rain to fall by suddenly chilling the atmospheric strata. During the night, and

and at all times when the wind blows violently, the salient angles of the mountains become in their turn much colder than the sheltered gorges, and it is they that condense the mists of the air and cause the rain. How many times in mountainous countries, when the sky is perfectly clear and blue, do we not see the high peaks enveloped in a mist like the smoke of volcanoes! These clouds which we perceive around the summits are found in warm air in the state of invisible vapours; it is the cold contact of the rocks or snows which has suddenly revealed them. The mountain peak thus announces to the inhabitants of the valleys that the atmosphere is saturated with vapours, and warns them of an approaching change in the temperature. The mountains thus constantly serve as meteorological indicators to the neighbouring population, and in each mass of heights they always look towards one of the largest peaks, to see if it has "put on its cap" of clouds.

Direct observations collected in various parts of the world have demonstrated that, all other things being equal, the annual precipitation of rain-water is in proportion to the altitude of the country, at least, to a certain height in the mountains. According to Keith Johnston, the average rainfall for the plains would be 22·6 inches per year in Europe, and for the mountainous districts, about 51 inches; this is about the proportion which is observed in Alsace. In the valley of the Rhine the quantity of rain is on an average from 22 to 22·8 inches in the year, while on the high Vosges it is from 43 to 47 inches.* Alsace therefore is in this respect a resumé of the entire continent. The Jura, arresting the passage of

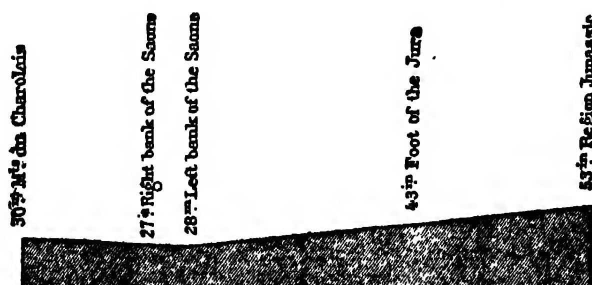


Fig. 127.—Rainfall on the two sides of the valley of the Saône.

the winds which bear the vapour drawn from the ocean, forces them also to let fall their burden of moisture. By tracing a transverse line

* Ch. Grad, *Hydrologie de l'Ill.*

to the valley of the Saône from the heights of Charolais to the mount-

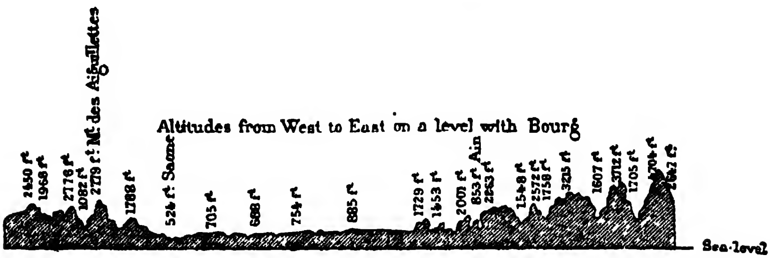


Fig. 128.– Altitudes along the sides of the valley of the Saône.

ains of Jura, M. Fournet has ascertained that the annual precipitation increases tolerably regularly with the altitude; from 27·4 inches on the right bank of the Saône it increases gradually to the parallel wall of the Jura; on the western side it becomes greater with the altitude, and thus from the height of the ground we could estimate the mean quantity of rain.

On the southern slope of the Cevennes, where the winds blow with such violence because of the rapid variations of temperature produced by insolation and radiation, the difference which is observed between the annual falls of rain is still more considerable than at the foot of the other mountains of France. Over the town of Arles the total precipitation is 17·7 inches; but at some 60 miles to the north the town of Joyeuse, situated in the valley of Ardèche, which overlooks the mountain rampart of Tanargue, received in 1811 as much as 67·6 inches, and the annual mean is about 51 inches. On the 9th of October, 1827, enormous quantities (28·7 inches) of water fell there in the space of 21 hours, more than falls on an average on the soil of France during a whole year. Hence the formidable inundations of the Ardèche.* To the east, in the valley of the Rhône, which the winds of the Mediterranean are able freely to ascend, the annual fall of rain is always much less.

On that side of the Alps turned towards the plains of Italy analogous phenomena are observed. The mountains which close the Adriatic Gulf on the north receive twice, and in certain valleys even three times as much rain as the plains of Padua and the lagoons of Venice. But in Europe it is principally on the shores of the ocean, where the west and south-west winds bring such a large quantity of vapour, that the action of mountains, or even of simple chains of hills,

* See *The Earth*, the section entitled, *Rivers*.

on the precipitation of moisture, is manifested in all its geological importance. At Lisbon the annual fall of rain-water is hardly 27·6 inches, while at Coimbra, in a valley indenting the interior, there falls on an average 135 inches of water, more than in most tropical countries. In the same way the little mountains of Westmoreland, placed crossways to the kind of funnel which the Irish Channel forms, receive as much as 150 inches. In exceptional years this enormous quantity of rain-water is much exceeded; and yet Liverpool, situated likewise on the coast of the Irish Sea, receives in the same space of time 34 inches of rain, that is to say, only one-fourth or one-fifth. As to the western coasts of Norway, which rise abruptly out of the sea, they are not exposed to less abundant rains than the hills of Borrowdale and Kendal in Great Britain. At Bergen the annual fall of rain is 105 inches, and undoubtedly other localities, whose fiords constitute real funnels where the wind from the open sea plunges laden with vapours from the Gulf-stream, are watered by a still more considerable quantity of rain.

The countries of the world where the rain falls in the greatest abundance are probably the coasts of Malabar, those of Aracan, and the lower slopes of the Himalayas. There everything favours the quantity of water to be very abundant in the rainy season: tropical heat, an enormous basin of evaporation, and the height and direction of the mountain ramparts, which must retain the clouds, all assist to this end. The Indian Ocean, an immense cavity in which the waters are incessantly revolving and the superficial evaporation of which is more active than that of all the other seas in the world, continually supplies the rain-clouds that the monsoon carries now towards the coasts of Africa, now towards those of Asia. There the mountains placed directly across the aerial current, force it to rise over their slopes, and thus to mix with the colder atmospheric strata. A real deluge results from this: black clouds charged with rain let fall their enormous burden, the valleys are inundated, and the torrents changed into rivers.

At Mahalabulechvar situated at 4461 feet high on the western slope of the Ghauts, the annual average of rain ascertained during a period of 40 years is 275 inches. At [redacted] at the same altitude, on the Garrow mountains, to the south of the valley of the Brahmapootra, the quantity of rain discharged annually by the clouds is much greater,—it is 550 inches; that is to say, it rains almost as much during the twelve months as at Alexandria during a century; in the single month of July, 1857, as much as 148 inches fell there.

It is probable that these enormous rainfalls have been even exceeded in several valleys of the Himalayas, for Thomson and Hooker

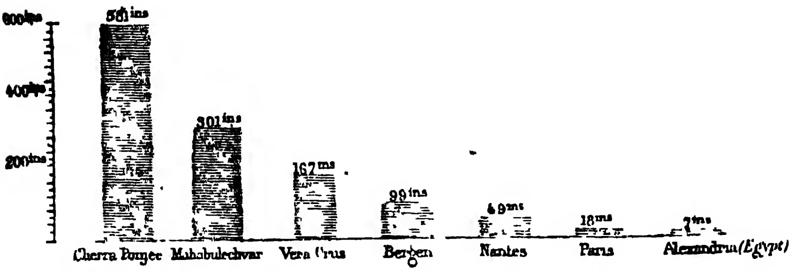


Fig. 129.—Comparative amounts of rainfall.

speak of a locality where the rain is not less than 470 inches in seven months, and where a temporary deluge of four hours, similar to the breaking of a waterspout, covered the ground with a liquid sheet estimated at 30 inches deep. In a single shower, therefore, this valley of the Indus had received proportionately as much water as France receives during a whole year. According to Cleghorn, the average of rain on the coast-lands of India was only 42·5 inches, scarcely the eighth part of that which falls on the mountains of the interior. It is from the enormous precipitation of moisture from the clouds brought by the monsoons, that the base of the first counter-forts of the Himalayas are bordered with the unhealthy zone of the "Teraï," whose jungles travellers are obliged to pass rapidly, so as to escape by dint of speed from fever and death.

Nowhere certainly in other regions of the torrid zone is the precipitation of rain favoured in so remarkable a manner. On the slopes of the Kiliman'djaro it rains almost every day during ten months; but the traveller, Von der Decken, who was the first to ascertain this meteorological fact, does not say that the rains fall as abundantly as in India. In the Gulf of Guinea the monsoons, which are precipitated towards the continent, meeting with but few mountains that present an obstacle, carry their rains far into the interior of Africa. The Antilles have not enough breadth to hinder the winds and clouds from deviating obliquely to right and left, and the greatest annual quantities of rain that have been ascertained there in the high mountain gorges do not attain 390 inches, which is 195 inches less at Pondicherry. On the coasts of Columbia the chain of the Andes, relatively but little elevated and here and there interrupted

by wide valleys, presents itself obliquely to the direction of the trade-winds; but in the funnel of the Gulf of Uraba and in the almost impenetrable forests of the province of Choco, the rain falls in truly prodigious quantities, hardly inferior to those of the Himalayas. It is to this enormous precipitation of moisture that the Atrato, a river relatively insignificant by the length of its course, rolls along a quantity of water greater on an average than that of the largest rivers in Europe.*

Whatever may be the difference between the rains in various climates, this phenomenon of a greater abundance of rain on the slopes of the mountains than in the plains, is a general fact over all the earth. We observe it in India as in Europe, in Patagonia as in the Antilles. Still we must not conclude from this that the precipitation of moisture increases in an indefinite manner in proportion to the height of the mountains, and that the summits always receive the greatest quantity of water under the form of snow or rain. On the contrary, it is certain that above the zone where the thickest clouds generally float the rain diminishes by degrees. The want of precise observations prevents us from indicating the average height of this zone in the various countries of the world, and consequently we cannot yet determine the laws of distribution of rain in a vertical direction. But methodical researches on the movements of the clouds will little by little furnish all the elements necessary, and will allow us sooner or later to point out on each mountain slope the spot where the greatest quantity of vapour will every year be transformed into water.

In the Alps of Switzerland this zone of the greatest precipitation is tolerably high, for the total bulk of snow-water and rain which falls annually at the pass of Great St Bernard exceeds by more than 39 inches that which is collected at Geneva, at the foot of the mountains. Below it is only 32·5 inches, while on the snowy pass it is on an average 79 inches. Figures are wanting to establish the fact that on other mountain chains the elevated slopes receive a much less quantity of water than what falls in the valleys opening half-way up. But this is a phenomenon not the less certain, owing to the researches already made on the mean height of the clouds. As to the mountain slopes which are not struck by the rainy winds, and the plateaux surrounded by terraces, they only receive in general a very slight proportion of rain, and a number of them are, owing to want of water, transformed into real deserts.† The peaks which

* See *The Earth*, the section entitled, *Rivers*.

† See below, p. 31.

rise above the atmospheric currents arrest the clouds en route, and only allow dry winds to pass. Thus the plateaux of Castile are only traversed by meagre rivulets, while through every valley of the Cantabrian Pyrenees there flows a pretty considerable river. It is the same in Columbia; on the abrupt coasts which the trade-winds strike against, the mean depth of rain-water is estimated at 81 inches per year, and on the plateaux of the interior it appears to be only 41 inches. At Bogota, in the centre of the plateau of Cundinamarca, it is 43·5 inches, hardly as much as on the high Vosges in the temperate climate of Europe.* Finally, the rain which falls on the high plains of the Deccan on the eastern slope of the Ghauts, would be considered insufficient in most countries of Europe, where however the evaporation is much less than in Hindostan. At Poonah, situated on the plateau immediately to the east of the mountains which overlook Bombay, the annual fall of rain is only 23·5 inches.

* Agostino Codazzi, Caldas, Illingworth.

CHAPTER XVI.

TROPICAL RAINS.—RAINY AND DRY SEASONS.—PERIODICITY OF RAINS.

The form and relief of lands, as well as the situation which they occupy relatively to the extent of ocean, are not the only facts that influence the greater or smaller precipitation of rain in various countries; we must also take temperature into account. All other things being equal, it rains more in a country the nearer it is to the equator, for the evaporation increases with the heat of the sun, and consequently the condensation of moisture produced by the conflict of the winds returns a greater quantity of water to the earth. Hotter than the temperate zones, the tropical zone is also watered by more abundant rains, in the same way as the temperate zones receive proportionately more moisture in the shape of rain and snow than the two polar zones.

Between the tropics the rains follow with tolerable regularity the apparent course of the sun, and the season during which they fall to the ground is thus clearly defined. In fact, the trade-winds become charged with an enormous quantity of watery vapour in passing over the seas of the torrid zone; but their temperature augmenting in proportion as they approach the equator, they acquire a greater and greater capability of holding moisture, and preserve their relative dryness. Nevertheless, as soon as the regular winds from the south-east and north-east have arrived at their point of meeting in the equatorial zone, things suddenly change; the two aerial currents mount together into the high regions of the atmosphere, their temperature is lowered, the vapour with which they are saturated condenses, heavy strata of clouds are formed above the whole of the zone of calms, and are precipitated in floods of rain. The water falls, indeed, in such great abundance that sailors are often able to collect from the surface of the ocean the fresh water that they need. The English navigators have given to these parts of the sea the expressive name of *swamp*, as if the sea were changed into a sheet of brackish water; for Frenchmen the entire region has become the *Pot-au-Noir*, probably because of those sudden showers and irregular winds which

succeed to the downfall of the rain. The zone of clouds which extends thus in a more or less continuous manner all over the ocean, is undoubtedly visible from the nearest heavenly bodies, and must resemble those whitish bands which our telescopes discover on the planet Jupiter.

The movement of the zone of clouds with the course of the sun over the ecliptic, causes the dry and rainy seasons to alternate regularly in the tropical regions. Thus the Antilles and the Republics of the American isthmus are successively under the great girdle of rainy clouds, and in the domain of dry winds. During the months of June, July, and August the sun, trailing beneath him the immense veil of vapours, is at the zenith of the countries near the tropic of Cancer; this is then the so-called winter-season or *hivernage*, vapours cover the heaven, and rain falls in abundance. As we may see by a comparison of the rain at Vera-Cruz and on the northern coasts of the

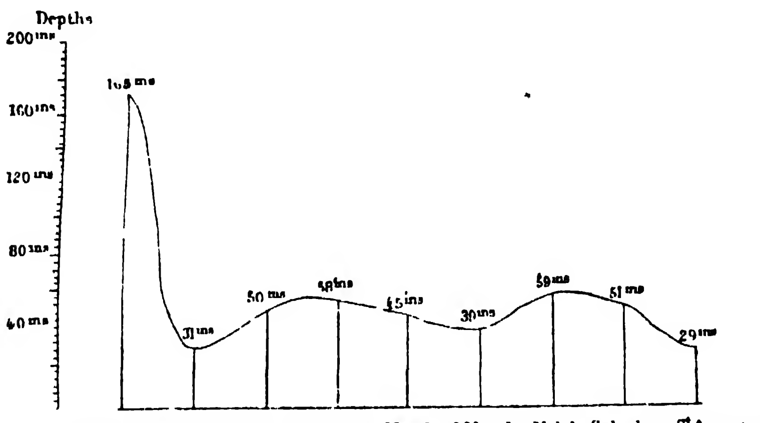


Fig. 130.—Rains around the Gulf of Mexico.

Gulf of Mexico, the quantity of rain that falls exceeds by double or triple the average proportion of water received by the border countries situated beyond the zone of "hivernage." In September, when the girdle of clouds has again passed southward, the trade-winds resume their normal march in the direction of the equator. They absorb the moisture of the land and sea, and carry it further to the countries sheltered by the zone of clouds; then it is the dry season for the Antilles and Central America.

In Columbia the year is divided into four periods, two dry seasons

and two wet seasons, produced likewise by the oscillation of the rainy zone. During the winter of the northern hemisphere the girdle of calms penetrates into the opposite hemisphere, and extends in breadth from the 2nd degree of north latitude to the 5th degree of south latitude. When New Granada is still under the influence of the trade-winds from the north-east the sky is pure and cloudless; this is the spring season, the *verano;* it rains only in the mountain valleys which cross the path of the winds. Towards the months of May and June, the girdle of calms is brought back to the north, and passes above the plateaux of Granada inundating them with rain; this is the first hivernage, the *invierno.* But the cloudy masses continue their march towards the north, and stay only after having attained the 12th or even the 15th degree of north latitude. Then the Columbian plateaux are outside the zone of precipitation for the second time, and subjected to the influence of winds greedy for moisture, which bring with them a new dry season. Finally, towards the months of November and December the girdle of calms again crosses the latitude of Bogota, and the thirsty land instantly receives rain from the sky, till the wide band of clouds has disappeared in the direction of the equator.*

To the south of the countries where the two annual passages of the cloudy zone cause the alternation of a double winter and a double summer, phenomena analogous to those of the Antilles and Guatemala occur. In the regions of the Upper Amazones, as in Central America, there are only two seasons, the rainy and the dry, but these follow each other in inverse order: when it rains on one side, the sky is azure on the other, when drought prevails to the south, the lands are inundated to the north. Besides, in both hemispheres the normal epoch and the abundance of the rains are variously modified by the form of the coasts, the relief of the plateaux and mountains of the interior, and the alternations of the monsoons. Thus the great rains fall in June and July at Calcutta, and at Anjarakandy on the coast of Malabar; at Madras the maximum is in November.

By a remarkable contrast, it is precisely at the time of the year when the heat ought to be greatest that the tropical countries are most refreshed by the precipitation of abundant *rains.* Extending like an immense veil, the clouds protect the earth from the heat of the sun, which is then at its highest in the heavens. The winter-time, during which the temperature is often lower than in the warm season, is nevertheless the true summer from an astronomical point

* Maury, *Geography of the Sea.*

of view. We can judge of the influence which the tropical rains exercise on the temperature by the accompanying figure, the two

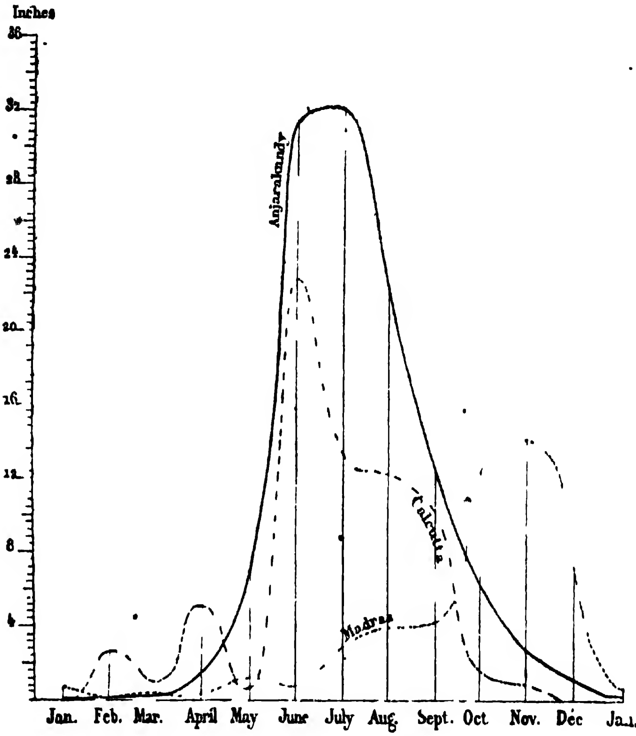


Fig 131 —Amount of monthly rain-falls at Anjarakandy, Calcutta, and Madras.

All Figs 131, 132

lines on which represent—one the monthly amount of pluvial water at Anjarakandy, and the other the thermometrical variations. Thus the oscillation of the zone of clouds results in equalizing the annual heat, and tempers the ardour of a summer which might be in the whole of the tropical zone, what it is in the Sahara. It is true that often one feels more oppressed in the rainy season than in that of the great heat, because of the enervating moisture of the atmosphere.

Besides, we must not think that during the tropical rains moisture is precipitated constantly or even frequently at all hours of day and night. On the contrary, in the greater part of the equatorial regions the rains obey a sort of rhythm. Ordinarily they only commence in the afternoon, because during the night and morning the atmosphere has not yet had time to be completely saturated with vapours; but

when the air can no longer absorb any more moisture, the storm breaks violently in the midst of rapidly condensing clouds. On many

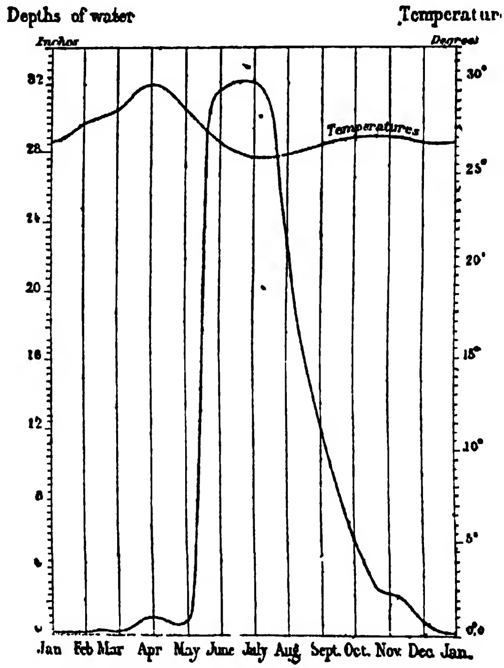


FIG. 132.—Amounts of rain-fall at Anjarakandy, with the corresponding temperatures

points of the coast-line of the sea of the Antilles, in Columbia and Mexico, the sky begins to discharge its burden of rain towards two o'clock in the afternoon; but the shower is expected, and all preparations for shelter are made beforehand, and in the evening one may go out-of-doors again without fear. In the same way in certain parts of tropical Brazil, the hours of the daily storm are so well foreseen that rendezvous can be appointed at the end of the rain. However, there are tropical countries more abundantly watered where the showers of each day last till a late hour at night, or even into the morning. On the open sea where the immense surface of evaporation can continually saturate the superincumbent atmosphere, the rains have a longer duration than on land, and they often continue for whole days.

CHAPTER XVII.

RAINS BEYOND THE TROPICS.—WINTER RAINS.—RAINS OF SPRING AND AUTUMN.—SUMMER RAINS.—RAINS OF THE POLAR REGIONS.

To the north and south of the zone of the trade-winds the rains, like the winds, present much less regularity than in the region of the equatorial calms, both in the quantity of rain that falls and in the time and duration of the rainy season. It is in the northern hemisphere especially that the precipitation of rain is accomplished in an unequal manner, for the surface is there more varied than anywhere else by the contours of continents, scattered islands, inland seas, and chains of mountains, which lie parallel, oblique, or transverse to the winds. Thus it is very difficult in many countries to discover the general order in which the rains succeed each other; and so long as conscientious observations have not been made during any series of years, uncertainty must prevail in this respect.

However, the registers kept at the various meteorological stations of the northern hemisphere are already sufficient to show what is the normal distribution of the rains on this side of the tropic of Cancer. To the north of the variable limit where the trade-winds commence, and as high as a latitude of forty degrees, the rains fall almost exclusively during the winter. Around the basin of the Tyrrhenian sea, and on the coasts of Western Europe, they are distributed throughout the year, but it is especially in autumn that the greatest precipitation of moisture takes place; more to the north it is the summer which is the especial rainy season; finally, in polar countries it is in the winter that the condensation of the clouds produces the most rain and snow.

The direction of the winds is the true cause of this unequal distribution of the rain-fall according to the various parts of the year, for beyond the equatorial zone most of the showers are, so to speak, not formed on the spot by the condensation of the ascending vapours, but are brought from afar by the currents of the atmosphere. During the winter of the northern hemisphere the whole system of trade-winds

is attracted to the south following the sun, and consequently the aerial counter-currents which return towards the Arctic pole can descend again to the surface of the globe in the neighbourhood of the tropic of Cancer.* The vapours with which these winds are charged are then condensed into rain in consequence of the mingling of the air which carries them with other and colder atmospheric masses; this is the rainy season. But when the sun approaches the equator, bringing with it towards the north the entire system of winds, the counter trade-winds of the south-west cannot then approach the surface except towards the middle of the temperate zone. The sky becomes bright again in the regions which had been inundated with rain; a relatively dry period commences in the spring, and lasts until the sun has again crossed the equator towards the southern lands. This alternation of the seasons is accomplished with great regularity on

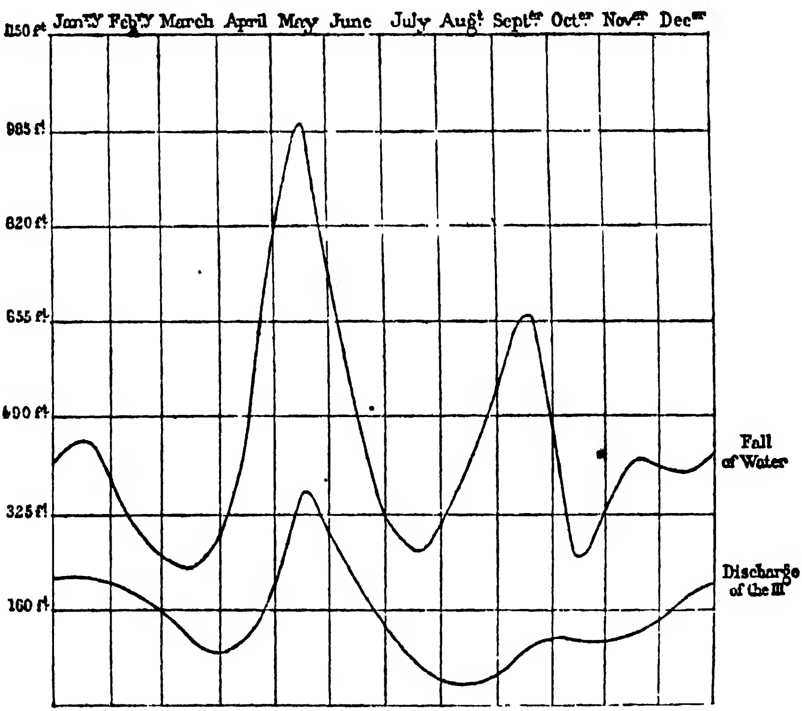


Fig. 133.—Amount of rain-fall in the basin of the Ill, and mean discharge of the River, during the year 1856.

the coasts of California and Oregon, at Madeira, in Algeria, and on

* See above, p. 250.

the coasts of Portugal. It is thus that at Lisbon only 0·16 inch of rain falls in July, whilst in December the total precipitation is 4·9 inches. At Naples and even at Rome summer droughts rarely disturbed by showers follow the winter rains.

As to the region of the spring and autumn rains, it ought to comprise the countries over which the returning trade-winds blow at the epoch when the sun is at the zenith of the equator; this is the equinoctial period of March or September. In certain countries in the south of Europe, and especially in Provence, we observe, in fact, that the rains are most abundant in spring and autumn. Even in Alsace the greatest quantity of rain falls in Spring, and flows into the tributaries of the Rhine, as the accompanying figure borrowed from a work of M. Charles Grad * shows; but with some exceptions the maximum of autumn is generally the highest of the two, and that of the spring ends by disappearing entirely in a

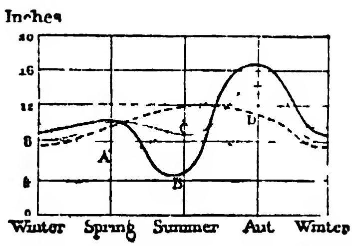


Fig. 134.—A. Western France. D. Eastern France. B. Basin of the Rhone to the South of Viviers. C. Basin of the Rhone to the north of Viviers. Autumn rains in France.

northerly direction. The western coasts of France and the British Islands are comprised within this zone where the autumnal rains

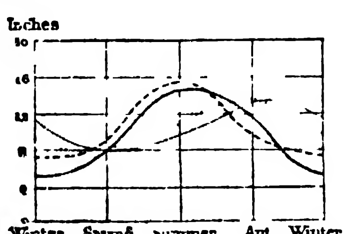


Fig. 135.—Autumn and Summer rains in the temperate regions of Europe.

regularly predominate. The true cause of this excess of precipita-

* *Hydrologie de l'Ill.*

tion during the autumn season, compared with spring, has not yet been proved; it must doubtless be sought in the fact that, under the influence of the various atmospheric and marine currents, the fall of the temperature after the heat of summer is accomplished in a relatively abrupt manner. The descent of the thermometer in autumn is more rapid than its ascent in spring. This is the result we obtain from most of the meteorological tables kept in the countries of Europe and North America.

More to the north, in the temperate zone, it is no longer in autumn but in summer that the rains water the earth with the greatest abundance. In the whole of central Europe, from the Vosges to the Ural mountains and beyond to the shores of the sea of Okhotsk, the greatest precipitation of moisture takes place in the warmest part of the year. This is because the sun, being then above the tropic of Cancer, has brought back to the north the entire system of the trade-winds and counter trade-winds; these latter, therefore, descend to the surface of the earth in high latitudes only, and there alone, in consequence of their conflict with the cold winds of the polar regions, is produced this notable increase of rain, owing to vapours brought from the tropics.

On the other side of the equator it is in exactly the opposite way that the counter trade-winds of the north-west, travelling with the sun, determine the greatest precipitation of moisture over the countries towards which they sink. As to the snows of the two polar zones, they fall most of all in winter, that is to say, during the long night which lasts several months, for the temperature of the atmosphere is then too low to retain in suspension the moisture brought by the equatorial winds.

CHAPTER XVIII.

COUNTRIES WITHOUT RAIN.—GEOLOGICAL ACTION OF RAINS.—CONTRAST OF THE TWO HEMISPHERES.

Thus in all parts of the earth, from the equator to the poles, the rain is distributed with a certain regularity according to the seasons. In many regions it falls exclusively during a fixed period of the year, in other countries the alternation is not divided so clearly between the rainy and the dry season. It often rains during the winter months as well as during the summer months. But a regular oscillation is observed between the two periods of the greatest and least precipitation. Still there are certain countries where rain is almost entirely wanting, and these countries are found for the most part situated precisely in the neighbourhood of the equator and the tropics, where the waters, heated by the sun, furnish the greatest quantity of vapour to the atmosphere. In regions like the coast-line of Peru, which stretch at the foot of high mountain-ridges rising on the path of the rainy winds, the constant dryness of the atmosphere must be solely attributed to the form of the surface of our planet. It is sometimes sufficient to cross a single pass to ascertain the enormous difference which exists in a meteorological point of view between the two slopes. On one side the winds, laden with moisture, frequently let fall their burden of rain; on the other side the aerial currents, lightened of their vapours and heated by the reverberation from the white rocks and bare earth, greedily absorb, on the contrary, the little water which flows in the valleys. The trade-winds from the north-east and south-east, which discharge on the eastern slopes of the Cordilleras such an abundance of rain as to form the Japura, the Putumayo, the upper Maranon, the Apurimac, the Mamoré, and so many other mighty tributaries of the magnificent current of the Amazons, do not let a single drop fall on the western slope, which is transformed almost into a desert, and traverse the surface of the Pacific to a great distance into the open sea before having collected enough vapour to discharge fresh rains. On the coasts of Peru the

air is often misty; but through this whitish veil the blue sky can be always distinguished; the appearance of a cloud is a real event, and the whole population assembles to contemplate this unaccustomed spectacle. On the western shores of Mexico, where the winds are much less regular than in South America, the atmospheric disturbances occasion the fall of violent showers at times; but, as in Peru, the great mass of rain-water is retained by the plateaux, and mountains which rise to the east, across the path of the trade-winds and monsoons. More to the north the meteorological phenomena occur in an inverted order. The rainy winds which strike the summits of the Coast Range and Sierra Nevada are the counter trade-winds of the south-east; they abundantly water the slope which faces the Pacific. But beyond the Rocky Mountains they are entirely dried-up, and the deserts of Texas, New Mexico, and Colorado would be absolutely without water if the monsoons from the south did not bring some moisture. The mean quantity of rain which falls in the solitudes to the west of the Mississippi is estimated at two inches only.*

But in the neighbourhood of the tropics, and even some way into the temperate zone, there are other regions freely traversed by winds laden with vapours, which are nevertheless very rarely watered by rains. A wide tract of land almost without water stretches diagonally across the Old World, from the western plains of Africa to the plateau of Eastern China. This zone disposed in an immense arc, the concavity of which is turned towards the north-west, comprehends a great part of the Sahara, the deserts of Egypt and Arabia, the high lands of Iran, various tracts of Tartary and China, and the plateau of Gobi. In the southern hemisphere the three continents, Africa, Australia, and South America, have also each their zone of dry lands situated in the neighbourhood of the tropic of Capricorn. In Africa it is the desert of Kalahari; in Australia it is the fearful solitudes which explorers have to traverse on their way from the southern colonies to the Gulf of Carpentaria; in South America it is the Pampas. If these several countries to the north and south of the equator are thus destitute of rain-water, the cause is principally the trade-winds, which, in their regular passage across the continents, constantly absorb fresh quantities of vapour in proportion as they approach the zone of the equatorial calms; and their temperature also increases. Nevertheless, it would be very difficult to trace the exact boundary of the regions destitute of rain, with those where the precipitation takes place regularly, for all round the countries of

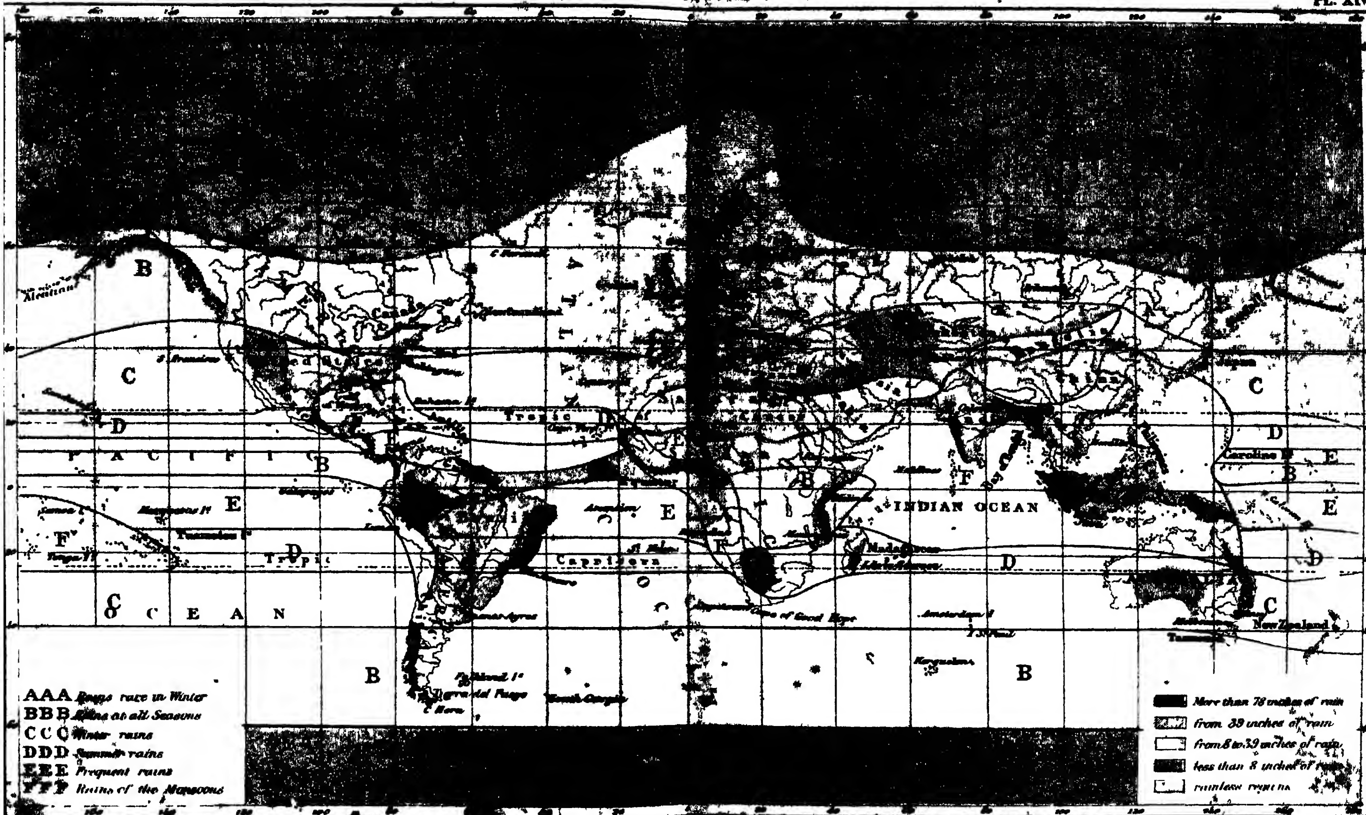
* See *The Earth*, the section entitled, *Plains*.

prolonged drought the monsoons form a sort of irregular border, changing year by year. Besides, the plateaux and groups of mountains placed in the midst of desert regions, the Djebel-Hoggar in the Sahara, the Demavend to the north of Persia, the huge pile of Cordova in the Argentine Pampas, raise their summits high into the air, and force the chilled winds to yield to them a part of the vapours that are carried towards the equatorial zone. As to the plateau of Gobi, situated in great part beyond the zone of the trade-winds, the dryness of its climate is caused by the mountains which surround it, and by its distance from the sea.

Fig 136 — Ravines in the Craters of Réunion

As is shown by the aspect of all deserts, rain is the great geological agent on the surface of the earth. The immense indentations

RAIN MAP OF THE WORLD



by Erhard

Vincent Brooks Day & Son Lith

CHAPMAN & HALL, LONDON

made in the edges of plateaux and the flanks of mountains, are due for the most part to the action of rains and streams which wear away the clays, carry the sands along with them, lay bare the rocks and drive them before them, and also assist in the destruction of the shores. In all the rainy countries whose surface is greatly varied, it is absolutely impossible to recognize what was the primitive aspect of the land, so much has been done by the rains in sculpturing anew the fissures and inequalities produced at first by other agents. Thus in most of the volcanic countries, and especially in the Island of Réunion, the ancient craters have been hollowed out and worn by the rain, and finally transformed into circles similar to circles of erosion. According to Lyell, the Val del Bove, which opens on the eastern slope of Etna, is also an ancient volcanic crater, whose walls have been partially destroyed by the rains.*

Where rain is wanting the surface presents a singular monotony over vast tracts. It is undoubtedly to the absence of rain and the dryness of the atmosphere, that the Argentine Andes owe the peculiar uniformity of their relief; there we see none of those long valleys, those deep ravines and wide crumbling circles, which give such a picturesque character to the architecture of the Pyrenees and the Alps. Since the epoch when the waters of the sea retired, carrying to the foot of these mountains of the New World the enormous heaps of rolled pebbles which we see there now, the snows and rains have not yet fallen in sufficient abundance to hollow out the declivities and cut them into valleys and counter-forts. From below the rampart of mountains presents the aspect of a uniform and blackish wall, above which rise here and there a few peaks striped with white lines. The plateau, from 13,000 to 14,000 feet in average height, upon which these isolated mountains rise, is in many places almost perfectly level over a breadth of 50 miles. A few low hills scarcely break from time to time the monotony of the great plain; in the deepest depressions small lagoons of water, almost always very saline, are seen. The vegetation is absolutely nothing, not because of the intensity of the cold, but because of the dryness of the air and the violence of the wind which blows in these high regions; one single plant grows at the height of 13,000 feet, the *Llareta*, a kind of lichen with a strong root, which spreads over the rocks like a green mould. The snow which rarely falls on these heights melts or evaporates when it has barely escaped from the clouds. In the middle of the day these snow vapours rise in thin clouds, which

* *Philosophical Transactions*, 1858. See, also, *The Earth*, the section entitled, *Volcanos*.

are lost at great heights in the blue atmosphere; one would say they were fireworks ascending into the sky.* The air of these regions is sometimes so dry, that the skins of travellers crack and their nails break like glass.†

The exact proportion of rain which falls in the various countries of the earth, so indispensable to our knowledge of meteorological laws, is thus found to be also of the greatest importance in a geological point of view, since it enables us to explain the form of the mountains, the general aspect of countries, and the state of the vegetation which covers them. This is not all,—the distribution of rain is likewise an astronomical phenomenon. For by the comparison of the amounts of rain-fall observed over the surface of the globe, one can learn exactly the contrast which is presented between the two hemispheres in respect of the precipitation of moisture. And this contrast, whatever its importance may be, is intimately connected with the unequal distribution of heat in the two halves of the planet, and in consequence of the form of the orbit which the earth describes round the sun.

It results from a comparison of observations that the greatest proportion of rain-water falls in the northern hemisphere. According to Keith Johnston, who unfortunately was able to quote but a somewhat limited number of meteorological facts, the amount of rain which falls on an average during the year on the surface of the earth, to the south of the equator is 26 inches; to the north it is about 37½ inches; that is to say, about half as much again.‡

These figures seem a little too high, and will undoubtedly be sensibly modified by future researches, which embrace a greater number of stations and a longer period of years. But it is very probable that the difference noticed between the two hemispheres in respect of the precipitation of rain-water will always remain considerable. In fact, it is in the northern hemisphere that we find the zone of equatorial calms where the rains fall in the greatest abundance during almost all the year. It is in the northern hemisphere, too, that the monsoons attracted by the heated continents discharge those prodigious showers, and supply the earth in a few weeks with more water than falls from the clouds in other climates in several years. Almost all the great rivers, also, with the exception of those which flow into the estuary of La Plata and the tributaries of the right

* Martin de Moussy, *Confédération Argentine*, vol. i. p. 187.

† Tschudi, *Ergänzungsheft Mittheilungen von Petermann*, 1860.

‡ *Physical Atlas.*

bank of the Amazons, have their source in the northern hemisphere.* The continental surface which is found to the north of the equator is three times the extent of that which stretches to the south, while the amount of rain, estimated roughly according to the yet incomplete data which we possess, is at least five or six times as great.

Now, by a remarkable contrast, the northern hemisphere, which receives the greatest quantity of water, supplies the least proportion of it. In fact, the ocean restricted to the north by continents, spreads on the south of the equator so as to cover almost the entire circumference of the earth. It thus presents to the solar rays an immense surface of evaporation, incessantly feeding the clouds of the atmosphere. In this way that half of the globe which furnishes the most vapours is that which receives the least rain in exchange; a circuit of the aerial currents is therefore necessarily established between the two hemispheres, and thus equilibrium is maintained. It is in great part the vapours from the Southern Atlantic, and perhaps also from the South Sea, that supply the rivers of Europe.

* See *The Earth*, the section entitled, *Rivers*.

BOOK IV.—THUNDER-STORMS, AURORAS, MAGNETIC CURRENTS.

CHAPTER XIX.

HEIGHT OF THUNDER-CLOUDS.—DISTRIBUTION OF THUNDER-STORMS IN VARIOUS REGIONS OF THE EARTH.—COURSE OF THESE PHENOMENA.

The condensation and the precipitation of watery vapour are always accompanied by electrical phenomena; but this powerful force, which acts incessantly on the surface of the globe, does not manifest itself in a visible manner in ordinary rains, for by them the atmospheric equilibrium is hardly disturbed. But when the clouds are suddenly condensed, and when the ground and the different strata of air are very different in temperature and electrical tension, harmony can only be re-established by violent discharges, accompanied by lightning. It is then that we see in the sky, which is black with clouds, the magnificent spectacle of those dazzling flashes which spread in sheets or shoot in long zigzag darts. One instant the terrible light fills the sky, then space is covered anew with darkness, and we hear bursting from the gloom the immense voice of the thunder which reverberates in dull echoes from the clouds and the ground. In violent thunder-storms the deflagrations sometimes follow each other so closely that the horizon is lit up all round with one continuous flash, while crashes and long rollings of thunder echo from various points of the sky at the same time, and rain falls in torrents from the rent and broken clouds. Often, too, these storms shower upon the ground a mass of hailstones formed of concentric layers of frozen water surrounding a small crystal, sometimes very regular in form. Every one of these storms, however, differs in its proceedings. Some are simply passing phenomena, others are electric whirlwinds, or they may even be considered as real cyclones. In these terrible tempests lightnings six and even nine miles long have sometimes been seen.

The principal zone of thunder-clouds extends at a considerable elevation above the ground, as is easily ascertained on heights. "Mountains attract the thunder," say the proverbs of almost all nations; and it is in fact on the great elevations of the terrestrial surface where the clouds strike and are condensed into water, that the electrical discharges most frequently take place. Besides, isolated and pointed rocks must act as so many natural lightning-conductors, and they are consequently much oftener struck by lightning than the lower walls of the mountain-gorges. It is to the repeated action of these phenomena that we must attribute the singular magnetic state of those rocks, near which the mariner's compass is disturbed, and takes, without any apparent rule, the most various directions. Forbes and Tyndall cite a remarkable example of this phenomenon on the Rieffel Horn of Monte Rosa at more than 9000 feet high. Humboldt has seen rocks split by the lightning at the summit of the mountain of Toluca in Mexico, at 15,000 feet above the level of the sea. Messrs Peytier and Hossard have observed some Pyrenean storms which were formed at still greater heights. In a general way we may say that the height of these electrical storms is that of the great "cumuli," from which they take their origin.*

Thunder-storms, like simple rains, burst more frequently in the elevated gorges of mountains turned towards the sea than anywhere else. It was because of the numerous tempests which assailed the rough coasts of Epirus and Illyria that the Greeks made the Acroceraunian mountains the seat of Jupiter, "the hurler of thunder;" still these mountains are little visited by storms in comparison with several chains which rise in the tropical zone on the shores of the ocean, and transversely to the direction of the rainy winds. Thus the Sierra Nevada of Sta Martha in Columbia has a storm every day, and the few travellers who climb one of these great peaks above the zone of tempests may expect, from two o'clock to four o'clock, to see the magnificent spectacle of a tumultuous sea of clouds, all trembling with lightnings, unroll beneath their feet.

In general thunder-storms are most numerous in a country where rains are most abundant. The zone of equatorial calms and that of the monsoons where moisture is precipitated in such considerable quantities, are also the regions of the earth where it thunders most frequently. At Bengal the annual number of thunder-storms is from 50 to 60; in the Antilles about 40 are counted per year; under temperate climates there are only about 20, and these occur almost always

* Becquerel and Ed. Becquerel, *Eléments de Physique Terrestre.*

during the warm season. In Eastern Europe it is almost unexampled, so to speak, that they break out in winter. But on the western coasts

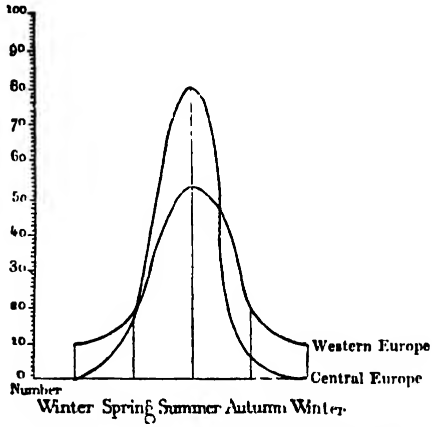


Fig. 137. Average amount of storms in Europe.

of the continent, which are subject to the tropical influence of the Gulf-stream, these stormy conflicts of the air take place also in the cold season. It is a curious fact that it is in winter that the greatest quantity of hail falls in Great Britain. In the direction of the poles

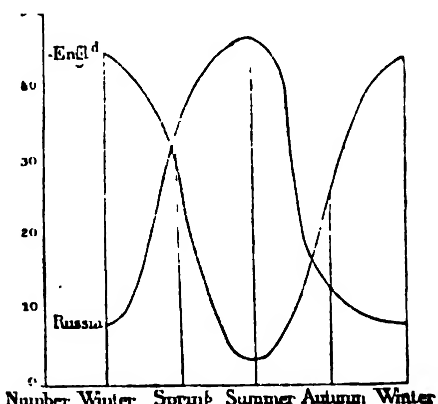


Fig. 138.—Proportion of hail-storms during the seasons in Russia and England.

the number of storms gradually diminishes. In the north of Europe thunder is a very rare phenomenon, and it is even said that in Iceland and on the coasts of Spitzbergen, that is to say, precisely in

those countries where the magnetic aurora shines, lightning has never been seen in the sky. As to the countries of the tropical zone, which do not receive any rain like the coast-line of Peru and Bolivia, it does not thunder there either. The lightnings which are sometimes seen by mariners sailing towards the open sea from the coasts are merely reflections of those that escape from the clouds at hundreds of miles to the east, on the eastern slopes of the Cordilleras.

As the number of tempests diminishes gradually from the equator to the poles, so are they reduced little by little in the open sea in proportion to their distance from the shores. This is a pretty general rule, at least in the seas of the torrid zone and the Antarctic Ocean. According to Arago and Duperrey, who have collected all the observations made before them on the tempests of the sea, no sailor has ever heard thunder in the middle of the South Atlantic nor in the great ocean of the south between Easter Island and the Island of the Antipodes. It is because of the relatively small number of storms breaking out on the open sea that ships, which attract lightning by the form of their masts, have been able to escape being struck.

Taken as a whole, the thunder-storms of Western Europe follow the same general direction as the tempests, and often accompany them on their course. This is shown most clearly by the meteorological maps of France, drawn up since 1865 at the Observatory of Paris. The storms are not there purely local phenomena, as was even recently supposed; but, on the contrary, they form part of the general system of atmospheric changes.* It is proved by thousands of observations made systematically in different parts of the French territory, that almost all the thunder-storms come from the ocean; very often the inhabitants of the coasts hear the rumbling of the thunder several hours before the storm breaks over the continent. In the same way in Germany, and even in Russia, thunder-clouds from the enormous basin of evaporation of the Atlantic come from the west and south-west.

It is, therefore, in quite an exceptional manner that rapid ascending currents, charged with moisture from the lakes and rivers, produce storms in the very interior of the continents. But on the various points of their path thunder-storms from the ocean are generally much modified by the medium through which they are propagated. Above regions differing from one another by the irregularities of the ground, nature of the soil, vegetation, and climate, the thunder-storms pass by abrupt passages, from relative calm to fury; here the

* *Atlas des Orages Rédigé par l'Observatoire de Paris.*

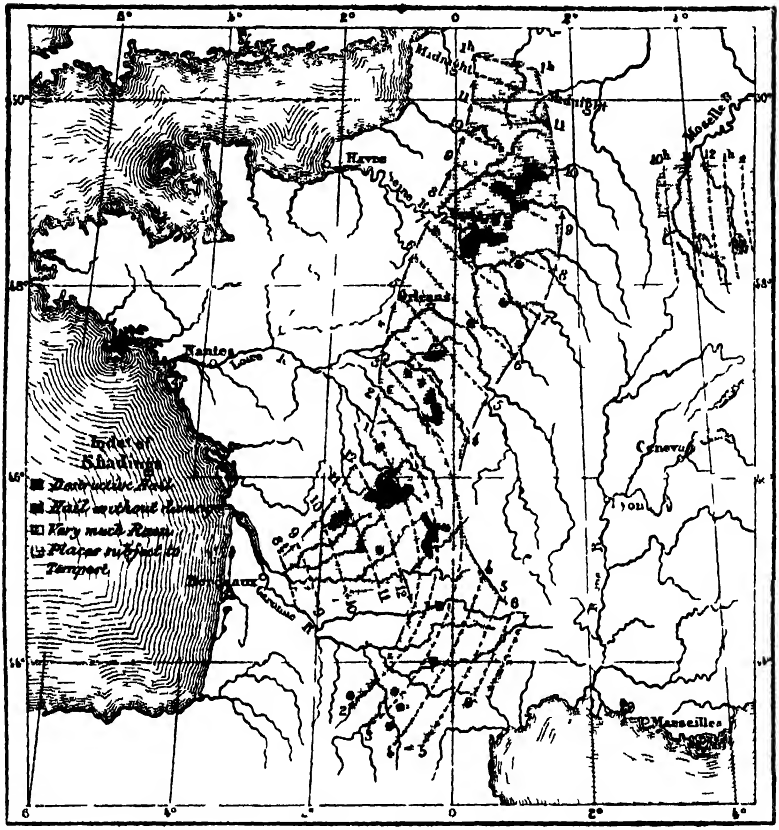


Fig. 139.—Storms on the 9th of May, 1865.

thunder rolls incessantly, and hail beats down the crops; there the clouds only discharge rain, still further, the wind drives the torn clouds before it without a single drop of rain falling. It is because of these great inequalities in the advance of the tempests that it is often difficult to recognize a regular series in the disturbances which succeed each other over distant parts of the same country.

The secondary storms which are formed here and there on the track of the principal atmospheric current are the more influenced in their march by the accidents of the ground and the variations of temperature, the less considerable they are, and the nearer they approach to the terrestrial surface. They also present the greatest variety of speed, and deviate frequently from their normal direction

to spread along mountains, hills, or forests. Thus, as M. Becquerel has proved in his meteorological studies on the centre of France, the greater part of the secondary storms regularly follow the course of the great valleys like so many aerial rivers, superimposed on the liquid rivers which roll below. When a thunder-storm, after having originated on a lateral plateau, directs itself obliquely towards a valley, it changes its course above the river, and never fails to follow its meanderings either up or down, as if it formed a bed for its own course in the great fosse of the valley. The storms which proceed at right angles to the direction of the river are the only ones which turn neither to the right nor to the left to enter the great depression which is open to them, the force which tends to carry them along parallel to the valley not being powerful enough to cause them to deviate from their route.

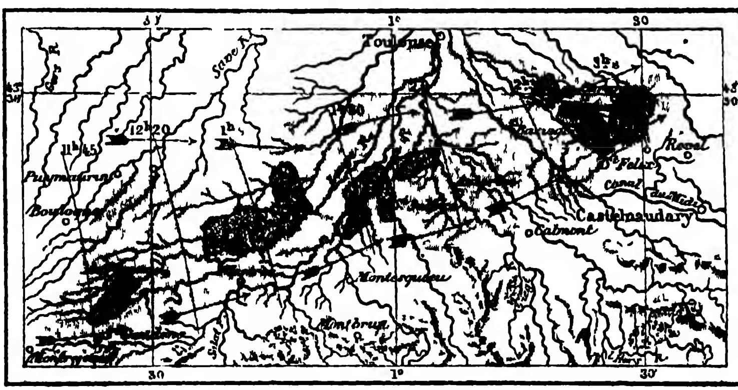


Fig 140.—Storm in the Plain to the north of the Pyrenees.

If the storms are attracted, so to speak, by the roads which the larger valleys present to them, it seems equally proved that they seek to avoid the forests. Thus the various currents of clouds charged with hail, which ravage more or less periodically the plains of the Loiret, pass round the forest of Orleans, or, at least, damage only its very edge. Whence arises this relative immunity of trees? Do they retard the current of air by their crowded trunks, and thus force it to let fall its burden of hail outside, and then to flow laterally, respecting the thick mass of the forest? Or do they act as lightning-conductors on the clouds, thus preventing the hail from being formed? These questions are still much discussed; but however it may be, it is certain that the forests often cause the hail to deviate, and that the

uprooting of trees often results in the modification of the regular course of the storm at the expense of agriculture.* The numerous

Fig 141.—Hail storms of Orleans. The grey tint indicates the region affected by the storms

meteorological maps drawn up by M. Becquerel and other learned men, do not allow of a doubt that the zones in which hailstones most frequently occur are really modified in their extent by the distribution of forests over the territory.

Not only the form and direction of the valleys, as well as the greater or less extent of the forests, give to the ground the power of calling up or allaying storms, but it seems, also, that the geological composition of the rocks exerts an influence of the same nature. Thus, to cite only two examples, certain masses of diorite in the Department

* Becquerel, *Comptes rendus de l'Académie des Sciences*, 1865, 1866, 1867.

of Mayenne dissipate or turn aside all the storms; while above the iron mine of Grondone in the Apennines, a cloud forms almost every day during the months of July and August, and regularly bursts in claps of thunder towards four or five o'clock in the afternoon.* Never-

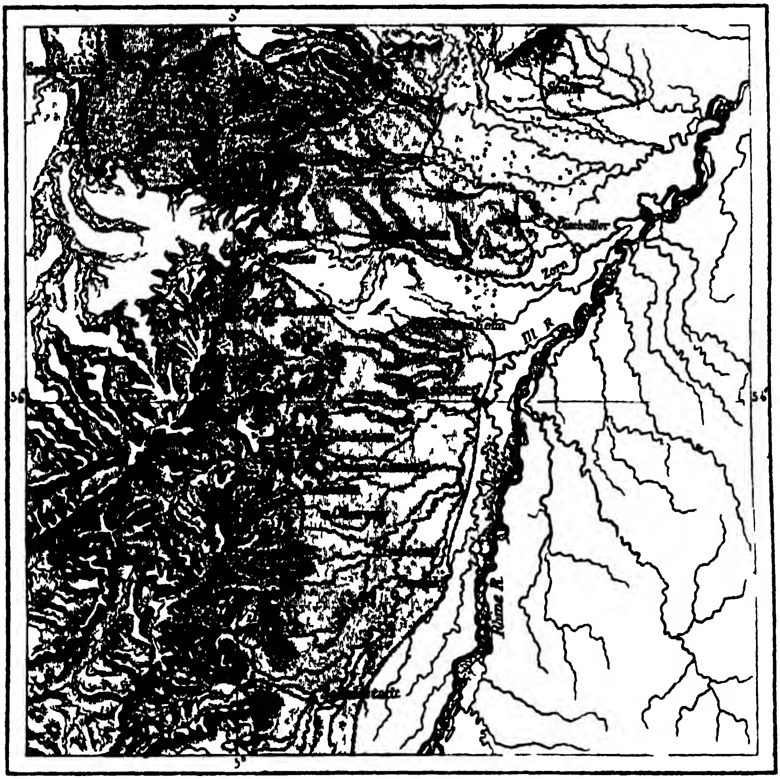


Fig 142 —Hail-storms of the Lower Rhine The part tinted indicates the regions of hail-storms

theless these are phenomena for which no certainty is as yet obtained. According to M Fournet, the savant who has best studied the laws of the rains and winds in the basin of the Rhône, the nature of the rocks and vegetable soil, the extent of cultivated fields, pasturage, and forests, exercise but a slight influence on the distribution of storms; the direction and depth of the valleys, the height and precipitancy of the salient points of the earth, are much more important in this respect.

This question of meteorology is still very obscure, as are those re-

* Blavier, Vicat, quoted by Zurcher and Margollé, *Météores*, p 119

lative to the fall of hail. Why under temperate climates is the zone of hail, which forms above the plains, almost always narrower than that of the storm itself? Why is the fall of hailstones such a rare phenomenon under the tropics, at least in the regions of the plains? Why during a whole century has it only hailed once at Havannah? Science is not yet in a position to answer with certainty. In regard to the formation of hail, the theories are contradictory to each other; and it is asked how hailstones, those heavy projectiles, weighing as much as 7 ounces to 10 ounces, can be crystallized in the heights of the air, and most frequently in summer, a little after the hottest hours of the day. What is most probable, is that those whirlwinds which always occur when two opposite currents meet, are the great producers of hail. In consequence of the centrifugal force the air is rarefied in the centre of the whirlwind, drops of water are congealed, and whirl in the great eddy, while at the same time cold air from the upper frozen regions is sucked down the immense funnel which is formed in the midst of the clouds, and thus the hailstones revolving in the vapours incessantly increase in bulk and number till they are dashed to the ground by the whirl of the grey clouds surrounding them. This theory, which is that of Mohr, Lucas, and Hann,* explains why hail is so rare in tropical regions, where the strata of frozen air are too high for the whirlwinds of clouds to be able to draw them down in their eddies. The appearance of the stormy nimbus, the small extent ravaged by hailstorms, the oblique fall of the projectiles, together with the violence with which they strike the earth, and the gyratory direction taken by the corn thus beaten, are facts which give a great degree of plausibility to this hypothesis of the German savants. In any case the power of the aerial currents, which are in strife during the formation of hail, must be truly formidable, for certain showers of hailstones are strong enough to form a kind of temporary glacier. On May 9th, 1865, the mass of hailstones which fell on the meadows of Catelot formed a bed over a mile long, and nearly half a mile wide, estimated to be equivalent to 700,000 cubic yards. Four days afterwards the hailstones had not disappeared.†

Many facts relative to the cause of storms are still unknown: no reason can be given for the fact that on the shores of the North Sea, of the Gulf of Bengal, and many other regions bordering on the ocean, thunder-storms almost always commence at the hour of high

* *Zeitschrift der Meteorologie von Jelinek*, No. 13, 1867.

† Mariotti, *Atlas de l'Observatoire.*

tide.* Another very strange phenomenon as yet unexplained is the appearance of those lightnings which dart from time to time from certain caverns in the cliffs of the Norwegian coast. Between Bergen and Trondhjem, on the shores of the Jörend-fjord, rises Mount Troldjöl, or the rock of wonders; from time to time, though more often when the weather is about to change, columns of flame and smoke, followed by peals of thunder, escape from a lateral fissure of this mountain. But the cavern in which these mysterious storms are developed is so difficult of access that no one has yet entered it. Nor has an attempt yet been made to explore another "laboratory of tempests," occurring in the southern of the two cliffs at the entrance to the Lyse-fjord; this perpendicular wall is 3600 feet in height,† and to reach the cavern it would be necessary to descend by means of ropes more than 1000 feet in the terrible abyss. From time to time, especially during a strong east wind, a flash of lightning is seen to shoot from the black rock, which expands and contracts alternately till it is finally lost before having reached the northern cliff. The sheet of fire revolves as it advances, and it is to this rotatory movement that the apparent expansions and contractions of the lightning are due. Rapid detonations make themselves heard with increasing force before the flame darts from the rock; a violent peal of thunder accompanies it, reverberating with long repeated echoes in the narrow glacier-formed corridor: one would think that a battery, placed in the cliff, was cannonading some invisible foe concealed in the opposite wall. Such were the strange phenomena of which the geographical engineer Krefting was the witness in 1855, during a topographical survey of the country. The inhabitants state that in fine weather, and when the wind has not blown from the south-east for several days, smoke of a yellowish grey colour is seen to issue from the cavern, and creep up the rock.‡

* Prestel, Bastian, Hann, *Zeitschrift der Meteorologie von Jelinek*, No. 17, 1867.

† See above, p. 132.

‡ Vide *Küsten von Norwegen. Erganzungsheft, Mittheilungen von Petermann*, 1860.

CHAPTER XX.

POLAR AURORAS.

The violent tempests which are so frequent in the temperate, and still more so in the tropical regions, form a most striking contrast to the long and silent atmospheric disturbances, which make themselves apparent in darts of flame over the polar heavens. These are the Aurora Australis and the Aurora Borealis. When but slightly luminous they appear as a whitish or vaguely illuminated cloud in the direction of the pole, though often the existence of these phenomena can only be recognized by the sudden variations of the magnetic needle. These almost invisible polar auroras are frequent in the temperate zones, where we very rarely can contemplate the sight of the sheets of flame and rockets, which give such magnificence to the Grand Northern Auroras. In central and southern Europe many persons pass their lives without ever witnessing one of these beautiful spectacles of nature. The only silent displays of terrestrial electricity which they have seen, are those vague glimmers which often issue from the ground during dark nights. As Humboldt has observed, this telluric light is often sufficiently bright—especially in winter, when the ground is covered with snow—to enable one to discern the forms of objects at as great a distance as during twilight.

It is to Scotland, the Shetland Isles, Scandinavia, North America, or better still, to Lapland, the shores of Hudson's Bay, and the Polar islands, where long winter nights endure for several weeks, or even months, that we must go in order to contemplate these vast auroral displays in all their grandeur. In 1838 and 1839 a French scientific expedition, encamped on the shores of the Alten-fjord, under the 70th degree of north latitude, observed during 206 days 153 auroras, not reckoning 6 or 7 phenomena of this kind which were doubtful; and 64 of these took place during the period of 70 nights, which intervened between the 17th of October, 1838, and the 25th of January, 1839; so that the members of the expedition came to expect the periodical return of these exhibitions as a matter of course.

When the aurora was wanting the sky was almost always covered in a great part with clouds.

Auroras first appear as a faint glimmer on the northern horizon like an undecided daybreak. A large dark segment of black clouds, in which Bravais believed he recognized the mass of fogs which brood in the distance over the sea, spreads over the sky in the direction of the magnetic pole. Soon a curve of light shows itself above the thick stratum of vapours like an immense arch, spreading from one end of the earth to the other. The light of a yellowish white hue gains rapidly in brilliancy, without, however, extinguishing the luminosity of the stars which sparkle through it; it flashes, vibrates, and moves like a flame shaken by the wind; sometimes, too, it divides into symmetrical masses, appearing like the flaming openings of a building on fire, the façade of which has remained dark. Often a second luminous arch and a third or even several other more concentric arcs of fire form above the first, and stretch up towards the heavens. For some time these arches of light alone illuminate space; then we suddenly see coloured rays flash from the arches to the zenith, in convergent pencils, green at the base, golden yellow at the centre, and a red purple at the extremity, succeeding each other regularly, thus adding to the splendour of the light by the most dazzling beauty of their colours; and often, according to Hansteen, black or dark violet rays alternate with the rings of light, thus rendering them more brilliant by contrast. The beauty of the Aurora Borealis is due to the infinite variety of its changing forms even more than to its various colours. Now the two ends of the arch rise off the horizon, and the luminous sheet undulates and turns back upon itself like an immense fringed drapery; now the sheaves of rays suddenly arrested seem to unite in a golden cupola; often they are separated from one another as by columns of smoke, and the glimmering rays of the aurora are alternately extinguished and re-lighted. These rays, to which the Canadians give the name of "marionettes," or merry-dancers, vary incessantly in length and brilliancy; the earth itself being almost always covered with snow during the time when the magnetic light is most frequent, appears now clearer, now darker, by contrast with the flaming rays. At the magnetic zenith, towards which the southern pole of the needle is directed, the sky appears dark; but all round it the divergent rays which come from the northern horizon and spread further and further from each other towards the south, form a sort of crown. This is the most brilliant period of the phenomenon. Afterwards the splendour of the arches and rays diminish

gradually; they are seen to palpitate, so to speak, as if the stifled flame tried to revive, which is gradually extinguished, and there only remain here and there "auroral disks" emitting a feeble glimmer like the distant lightnings of a tempest; and then there only remains a vague phosphorescence on the whitish cirri. Usually the magnetic aurora completely ceases before the first faint glimpse of dawn begins to show itself on the eastern horizon.*

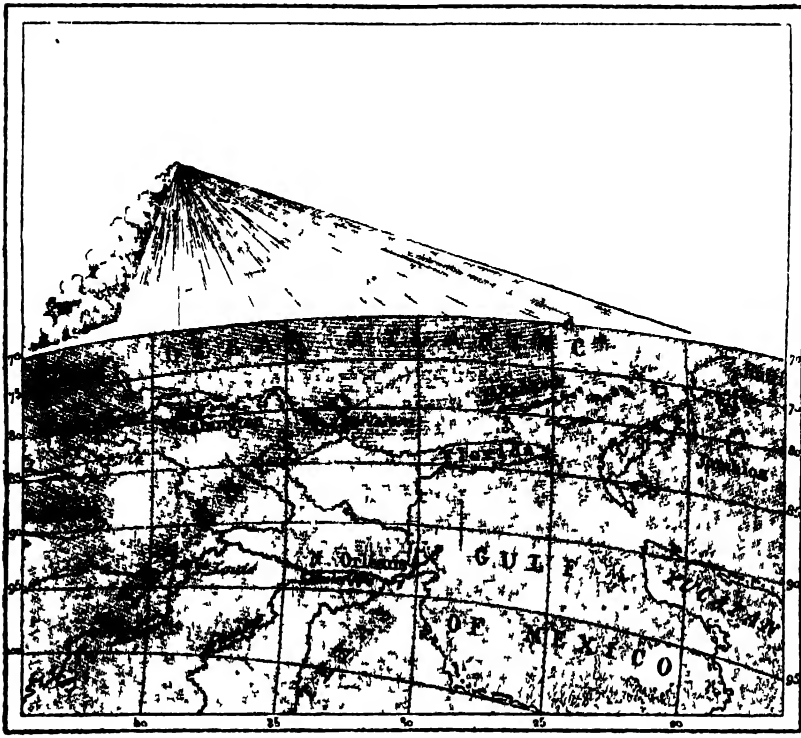


Fig 143.—Elevation and breadth of the Aurora Borealis of 28 August, 1859

Most natural philosophers assign a considerable elevation to the Polar Auroras. They think that these phenomena are generally produced in a very rarefied medium towards the upper limit of the atmosphere, and one is inclined to consider this opinion as very probable, seeing the analogy which exists between the brilliant colours of the arcs and rays of the aurora, and of those caused by passing an electric current through a vacuum. After having confirmed Han-

* Lottin, Bravais, Kaemtz, Becquerel, Loomis, &c

steen's idea that the Northern Auroras are not arches of light, as they appear by an optical illusion, but really circles surrounding the magnetic pole, and radiating at the same time towards all the circumpolar regions of the Old and New World, Bravais attempted to measure their height, and calculated that it is on an average 95 miles above the surface of the earth. Later, M. Elias Loomis, one of the most distinguished physicists of North America, compared and thoroughly discussed all the observations recorded in various latitudes of the two magnificent auroras of the 28th August and 2nd September, 1859, and the result of his researches tends also to prove that the mean elevation of the rays is very great. Thus, at the appearance of the former aurora the lower extremity of the columns was formed at 46 miles high, while their upper extremity attained the enormous height of 530 miles. The rays of the latter aurora extended upwards into the sky, from an elevation of 50 miles to 490 above the sea-level. By a like calculation of the height of 30 other auroras, it has been found that the extreme height reached by the rays is on an average 450 miles above the earth, and that the length of these brilliant rays is ordinarily about 400 miles.* It is true that earlier observers have arrived at quite different results. Some even believed that from the appearance of reflections in the clouds, that certain auroras occur in the lower regions of air at no greater elevation than ½ a mile or a mile. On the shores of lake Scavig in Scotland rays have been seen to issue from a rock; † but it is probable that these beams from below are secondary phenomena. However it may be, one cannot doubt that auroras have the atmosphere for their theatre, for they follow the general rotatory movement of the globe in its direction from west to east. The following figure indicates, according to the observations collected by M. Loomis, the position and relative height of the Aurora Borealis of September 2, 1859, which shone with such brilliancy above the United States and Central America. The upper fringes of the most southern sheet appeared vertically above the ground in Florida at the latitude of 25° 15′, and the general inclination of the aurora was precisely that which a magnetic needle freely suspended would have had in the same region.‡ The aurora which appeared four days before had its southern limit in Virginia towards 38° 50′ of latitude.

* *Smithsonian Institution, Annual Report for the year* 1865, p. 218, and following.

† Thienemann, Wraugel, Struve, Farquharson, quoted by Kamtz, *Lehrbuch der Meteorologie;* Felix Foucon, *Histoire du Travail,* p. 79.

‡ See below, p. 68.

The inhabitants of the North relate that auroras are often accompanied with detonations; nevertheless in no case has a scientific observer ever noticed the least sound which seemed due to them; for, as Becquerel has remarked, it would not be astonishing if the splitting of the plates of ice composing the cirri under the influence of the currents which traverse them caused a slight noise to be heard.

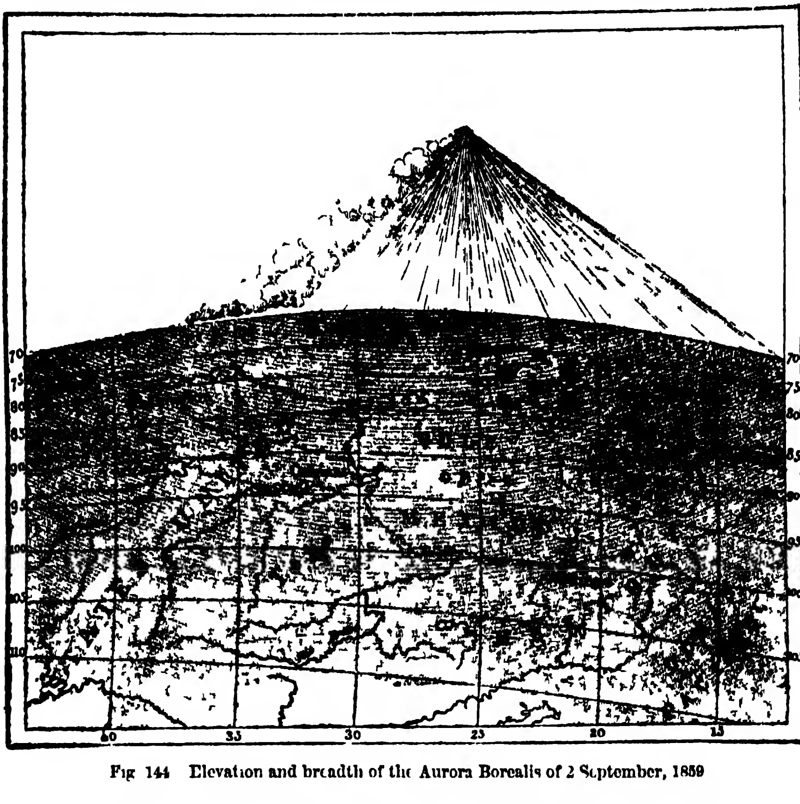


Fig. 144. Elevation and breadth of the Aurora Borealis of 2 September, 1859.

It is, in fact, in an atmosphere full of ice-crystals that the aurora most frequently occurs, which can be observed immediately after the cessation of the phenomenon, by seeing that clouds formed of icy particles are exactly in the direction whence the most brilliant light flashed. As Loomis justly says,* when one sees the light flash, it is natural to listen for a report, and one often hears that which one wishes to hear. It is thus that the ancient Germans perceived the hissing of the sea when the setting sun, like a red-hot iron, sank into it.

* *Aurora Borealis, Smithsonian Report for* 1865, p. 222.

An aurora may last for a long time, even for a day or two or even longer, for during the whole week which commenced August 28th, 1859, this phenomenon endured with greater or less intensity over the United States. In full daylight the disposition of the clouds and the restlessness of the magnetic needle revealed the invisible aurora. In 1786 Löwenorn even recognized after sunrise the luminous beams of an auroral light, so brilliant were they; but it is almost always during the night that this phenomenon takes place. The coloured rays which exercise such a great influence on the movements of the magnetic needle ordinarily appear before ten o'clock in the evening, and are rarely perceived after four o'clock in the morning. Bravais affirms that the auroras which he witnessed in his polar expedition commenced on an average about 7 hours 52 minutes in the evening. It was then that the luminous arch extended over the sky, soon after the rays darted towards the zenith, the auroral disks appeared, and towards half-past three in the morning the last glimmers vanished. In the same way, it is during winter, which is so to speak the night of the northern hemisphere, that the auroras advance to a greater distance to the south, and appear to the inhabitants of the temperate zone. The periods during which these magnetic disturbances most frequently occur are those of the equinoxes, at the commencement and end of the winter season. Meteoric phenomena of this kind are most scarce in the month of June. M. Boué, who has made a list of

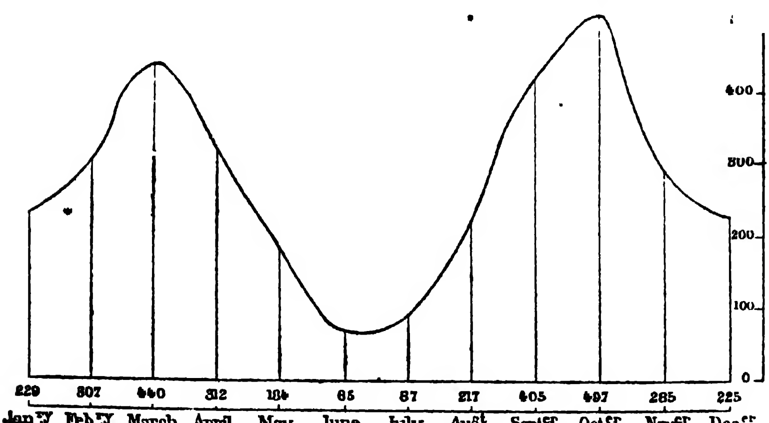


Fig. 145.—Monthly distribution of the Aurora Borealis; after Kamtz.

all the scientific observations of auroras up to 1860, enumerates only 7 for the month of June, while no less than 458 have been recorded

in March, and 498 in October at the time of the equinoxes. The accompanying figure may give some idea of the distribution of the auroras in the different months of the year. Figure 146, constructed on slightly different data, and according to a more logical method, as it represents the circle of the year, shows also that this is the average distribution of these aerial storms.

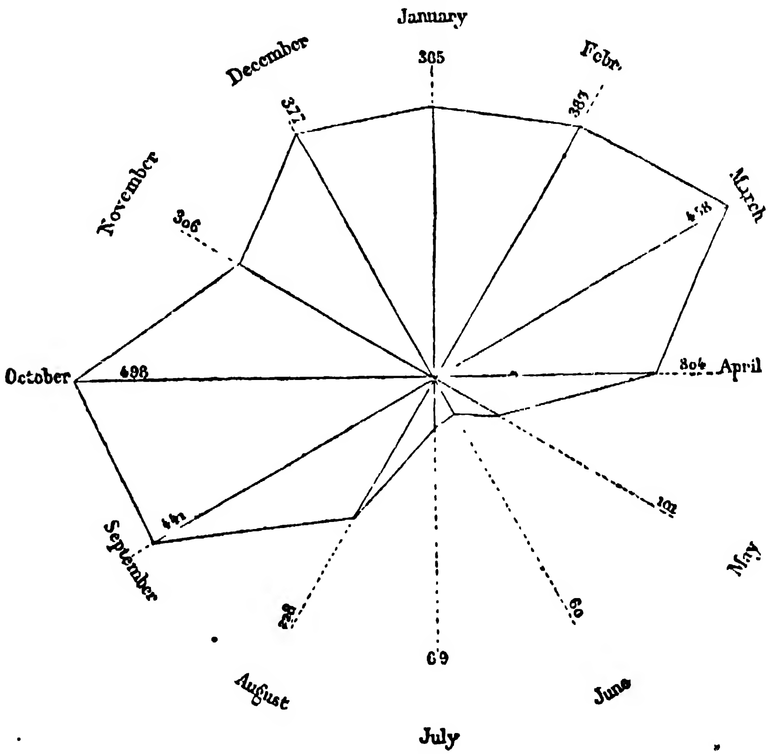


Fig. 146.—Monthly distribution of the Aurora Borealis; after Klein.

It is probable, whatever the meteorologist Glaisher may say, that the magnetic auroras have also their periodicity like all the other phenomena of nature. This is established by the catalogue of observations made in Europe and North America from the end of the seventeenth century to our own time. In 1697 the auroras were not at all numerous, but they gradually became more numerous till 1728, and then diminished. In 1755 they were of very rare occurrence, but became more and more frequent towards the end of the century;

in 1812 they were again at a minimum, but from the year 1825 they increased in number very rapidly, the average rising from one per annum to 30 and 40 in the same space of time. It would appear from the discussion of these facts that the cycle of auroras is one of 58, 59, or 60 years, and perhaps this period may itself be divided into six periods of ten years, corresponding, as Schwabe observes, with the regular variations of similar duration noticed in the number and size of the sun-spots; thus the fluctuations of the magnetic storms constitute an astronomical phenomenon. The accom-

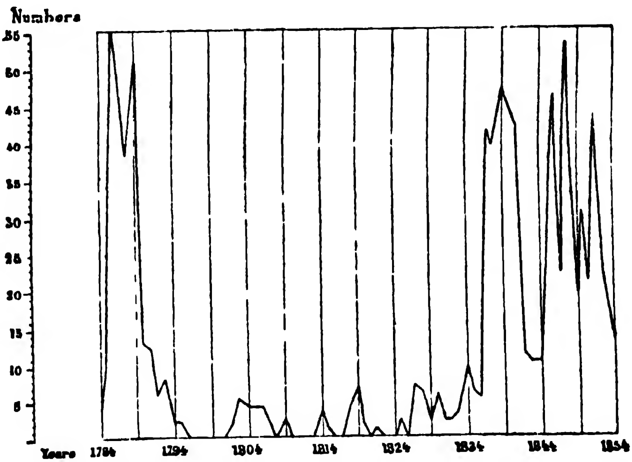


Fig. 147.—Auroras observed at Newhaven, Connecticut, United States, 1784—1854.

panying figure represents the series of auroras seen at Newhaven in Connecticut, during the 70 years from 1785 to 1854, comprising an entire period.

It is difficult to explain now, why the aurora appears more frequently in certain places of the Old and New World than in other parts situated at an equal distance from the magnetic pole. But it is incontestable that this latter point is not distant from the centre whence the auroral light radiates. In our hemisphere the culminating point of the luminous arc is found towards the direction of the peninsula of Boothia-Felix, where Ross saw the southern pole of the magnetic needle turn directly towards the centre of the earth. In Norway one sees the Aurora Borealis in the north-west; in Greenland directly to the west, at Melville Island Parry viewed it on the southern horizon. It must not be thought, however, that these magnetic

storms are very frequent in the high circumpolar regions; on the contrary, they are rather rare there, to judge from the accounts of travellers who have advanced farthest to the north. Hayes, during his stay in Smith's strait, only saw three phenomena of this kind.

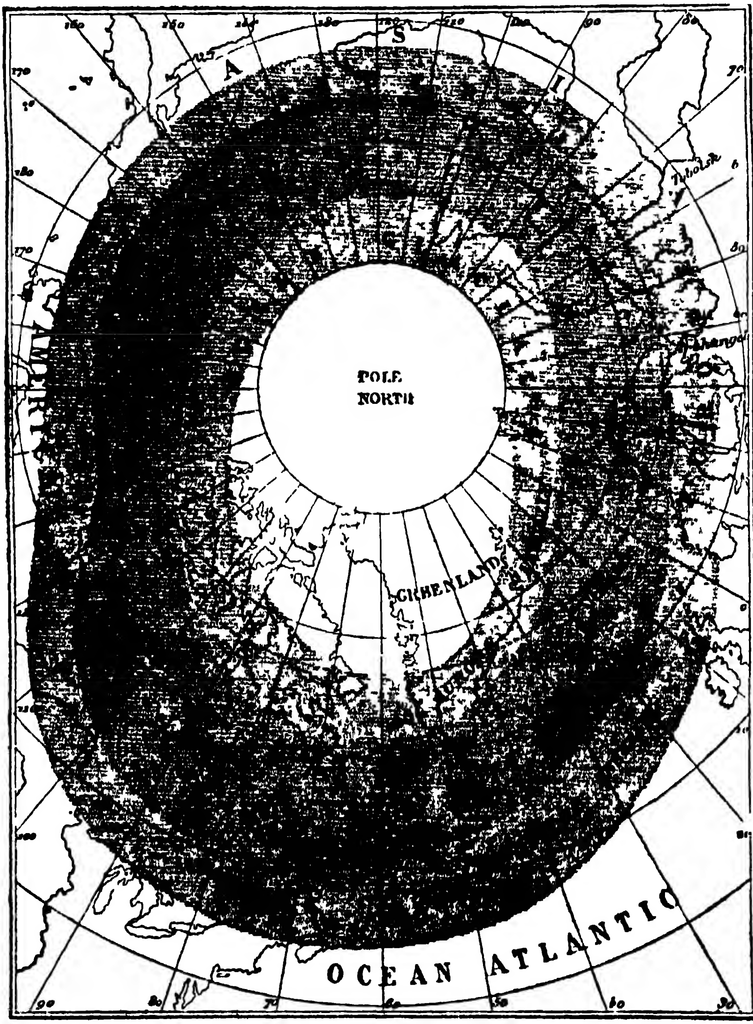


Fig 148.—Circumpolar zone of the Aurora Borealis.

In this northern space which is destitute of auroras, that is, in Southern Greenland, the Polar Archipelago, the North of Siberia

and Spitzbergen, there is a zone of 300 miles in diameter, whereabout forty times every year these northern lights are visible. The wider zone, which comprehends Hudson's Bay, Labrador, Iceland, and the north of Scandinavia, is richer, for eighty of them occur on an average yearly. Farther south extends a third zone, where these magnetic disturbances become less and less numerous; finally, in temperate regions these phenomena are rare, and towards the tropic of Cancer they are almost unknown. At Havannah only six auroras have been seen on the northern horizon in one hundred years.* These magnetic storms very frequently extend over nearly all the northern hemisphere at the same time, thus being very different from thunderstorms, which are usually confined to limited areas. The aurora of 28th August, 1859, was visible from California to the Ural Mountains, over a space of more than 150 degrees of longitude. That of four days later was seen at the Sandwich Islands, in the whole of North America, and in Europe, while at various stations in Siberia where the sky was cloudy, the variations of the magnetic needle testified to the atmospheric disturbances. It was on this occasion that the simultaneous appearance of the aurora on the two sides of the earth was first noted, both in the skies of the northern hemisphere as well as above the Cape of Good Hope, Australia, and South America. At the same instant in Labrador, at Philadelphia, Edinburgh, Algeria, and Valparaiso, luminous streaks were seen to dart from the polar regions; the storm was visible over more than a half of the planet. Thus the theory of the meteorologists that the northern and southern auroras occur at the same time in both hemispheres under the influence of the same current was confirmed. Of thirty-four auroras observed at Hobart's Town in Tasmania, between the years 1841 and 1848, twenty-nine coincided with the occurrence of the same phenomena, either in Europe or in North America, and all were marked by magnetic perturbations at the opposite pole. The fact, noticed by Forster, has since been confirmed by others, that the northern and southern auroras present remarkable contrasts in the colour of their rays, the light of the latter being of a pale blue, and less coloured than that of the arctic regions, thus forming a parallel to the way in which the hues of the rays of light differ at the two poles of an electric current. It may be considered certain that the extremities of the earth are in intimate connection with one another through the electric and magnetic currents continually circulating between them, both in the air and the mass of the globe.

* Elias Loomis, *Aurora Borealis*, *Smithsonian Report for* 1865, p. 215.

The researches of M. Becquerel and other natural philosophers have shown that it is probable that the superior strata of the atmosphere are almost always charged with positive electricity, and the warmer strata reposing on the surface of the land and of the sea, with the opposite kind of electricity. In consequence of the enormous evaporation from seas under the tropics, the moisture charged with positive electricity, rising to the upper atmosphere, maintains it in a state of constant tension; but violent thunder-storms, accompanied by very abundant rain, constantly tend to restore the equilibrium. Away from the tropical zone the higher and lower strata, less strongly electrified, no longer by sudden discharges, but by the silent action of the polar auroras, the two contrary electricities meet and are neutralized. Such is the theory. In any case it is certain that the auroras are electrical phenomena, since they act on the wires of the telegraphs like voltaic batteries, and since the colours of the arcs, beams, and auroral rays are precisely those of the ordinary electric spark passing through rarified air. At the same time auroras are magnetic phenomena, as is proved by their powerful action on the movements of the needle. Though produced in the atmosphere, and always accompanying the globe in its diurnal rotation, they are also very probably astronomical phenomena, obeying in their successive periods the cycles of the sun. Solar attraction, magnetism, electricity, are all convertible forces which work in concert to modify incessantly and then to re-establish the equilibrium of the atmosphere.

CHAPTER XXI.

TERRESTRIAL MAGNETISM.—DECLINATION, INCLINATION, AND INTENSITY OF THE MOVEMENTS OF THE NEEDLE.—MAGNETIC POLES AND EQUATOR.—ISOGONAL LINES AND THEIR SECULAR ANNUAL AND DIURNAL VARIATIONS.—ISOCLINAL LINES.—ISODYNAMIC LINES.

THE incessant mobility so characteristic of all the phenomena of climate is most especially manifested in the perpetual oscillations of the electric currents. Magnetism, this force as mysterious as the nervous fluid of organized bodies, in its invisible undulations vibrating from the poles to the equator, transforms this planet into a gigantic loadstone. The heat of the sun, which gives life to our globe, causes a continual tremor in the crust of the earth; currents of electricity (whose incessant movement from east to west in an opposite direction to the rotation of the globe, was discovered by Ampère) vibrate round the terrestrial surface like an immense coil, and maintain between the two poles a magnetic activity exactly similar to that which is produced in an induction coil.* All bodies are more or less influenced by these currents, and would arrange themselves in certain regular directions did not the bulk, weight, and cohesion of their particles hinder them from obeying the force acting upon them. The magnetic power of the earth is estimated by Gauss at 8464 trillion times that of our strongest artificial magnets, and yet this immense power has only been known for a comparatively short time. It was only in the year 1700 that Halley drew the first magnetic chart, and it is scarcely seven hundred years since the sailors of Amalfi, Provence, and Liguria learnt from the Arabs, or discovered for themselves, the movements of the magnetic needle, and this was the earliest recognition of this magnetic current pervading every atom of the planet. The Chinese navigators had known the remarkable properties of the compass for more than two thousand years before this.

In the earliest times it was believed that the needle pointed con-

* Barlow, Ampère, Becquerel, Sabine. See, also, *les Phénomènes de la Physique*, by Amédée Guillemin, pp. 702, 703.

stantly towards the polar star, or rather towards the pole of our planet; but the mariners who ventured as far as the Canaries and Iceland, or even those who confined their voyages to the Mediterranean, ascertained that the point of the compass did not invariably indicate the north, and that it diverged according to the latitudes by a greater or fewer number of degrees to the right or left of the normal direction. In 1268, Pierre Pélorin de Maricourt observed that it pointed 7½ degrees towards the east at Lucera in Southern Italy.* Columbus, on the voyage in which he discovered the New World, also observed that the variation of the compass was several degrees to the west of the astronomical pole; and it is said that he was obliged to reassure his sailors, who were alarmed by this unexpected phenomenon. Finally, the expeditions of Magellan, Drake, and other circumnavigators of the globe, established the greatest east and west variations of the needle from the north pole. These variations are known under the name of *declination.*

The deviation of the needle is not the only fact showing the magnetic action of the earth. In 1576 the Englishman Norman first noticed that the needle did not occupy a horizontal position in the latitude of Europe. On ascending towards the north magnetic pole the northern end of the needle dips more and more to the ground, and directly over the pole it becomes vertical; while on the contrary, as we descend to the south the needle becomes less and less inclined to the surface, till, on reaching an imaginary line called the magnetic equator, it is parallel to the ground. Beyond this it inclines more and more in the reverse direction, till, on arriving at the southern magnetic pole, the needle again becomes vertical, though now of course with its southern pole towards the earth: this is the phenomenon designated by the name of *inclination.*

Nor is this all: if we cause the needle to diverge from its normal direction, in returning to it it oscillates more or less rapidly according to the part of the earth where we happen to be. These oscillations, analogous to those of the pendulum, reveal the greater or less intensity of the currents, according to the distance from either pole, just as the extent of declination and inclination varies. These local differences, however, are by no means permanent. The direction and force of the magnetic currents which are produced on the surface of the planet change continually from hour to hour, from day to day, from year to year, and from cycle to cycle, conformably to laws of periodicity; but science as yet has not discovered all the elements.

* Détvezac, *Bulletin de la Société de Géographie*, 1859.

Among the grand manifestations of planetary life, of fluvial and marine currents, of the weight of the atmosphere, of the pressure of the vapour of water, of the alternations of the wind, of the variations of the climate, there are no phenomena which are more rapid and changeable in their alterations than those of terrestrial magnetism.

What is the probable cause of those currents which vibrate around the earth, and by which the compass is incessantly agitated, like the weather-cock under the pressure of the winds? The cause must be sought for not only in the movements of the earth, but equally in those of the sun, that great source of terrestrial life. The contrasting masses of earth and water, so unequally distributed in the two hemispheres, the difference of temperature between the aerial strata, the diurnal rotation of the planet around its axis, its annual revolution around the sun, the different rate of motion of the various parts of the surface of the globe, between the equator and the poles, the increase or diminution of its rapidity as it approaches or retires from the sun, the rotation of the sun, and finally the various periodical phenomena to which it is subject, its movement in space towards unknown regions of the heavens, the approach of a perturbing planet, everything, even the friction of the earth on the vapours which surround it, incessantly develop the magnetic energy of the globe, as an immense coil traversed by most powerful electric currents would do. In the ground which seems so impassive, but where so many germs give birth to life, whence so many wonders spring, the mysterious current circulates without ever resting, like an inexhaustible river. Under the influence of the sun it hastens or slackens its speed, moves in one direction or the other, and travels over the circumference of the globe, its equator and its poles. It obeys unceasingly the harmonious laws of nature, while only seeming to act capriciously because of the manifold interruptions causing the apparent irregularity in the succession of its periodicities. Just as the fine magnetic needle trembles and shakes like an affrighted creature in its box suspended at the ship's helm, so all over the earth magnetic currents oscillate and move untiringly; directly obeying the cosmical influences which make themselves only slowly felt on other functions of the globe, they may rightly be compared to the nervous phenomena in the animal organism. In consequence of their continual vibratory motion, the magnetic currents cannot be clearly traced on the map, and we must always confine ourselves to indicating their mean direction. There are not two instants in the year

when the movements of the needle are identical on the surface of the earth.

The poles towards which the compass points in the two hemispheres stray constantly around the astronomical poles of the planet, and it is never at the same point that their precise position must be sought for. In 1832 Captain John Ross, then sailing in the midst of the polar archipelago of North America, arrived in the neighbourhood of the north pole of the compass, since the point of his instrument was directed almost vertically to the earth. This point, towards which all the magnetic currents of the northern hemisphere then converged, was situated in the peninsula of Boothia Felix nearly 20 degrees to the south of the terrestrial pole (70° 5′ N.), and at more than 99 degrees to the west of the meridian of Paris; but since that epoch it has probably moved a few degrees to the east. The magnetic pole of the south has not been discovered by any navigator up to the present time. But according to the calculations of Duperrey, Gauss, and other savants, it would probably be found at 14 degrees 55 minutes from the Antarctic pole to the south of the continent of Australia. The two points of attraction of the magnet are thus each situated at the meridian of a group of continents; but they are not antipodal to one another, since they are found in the same hemisphere separated from one another by an arc of little more than 161 degrees, 29 degrees less than the semi-circumference. As to the magnetic equator, which is the line where the needle keeps perfectly horizontal to the surface of the earth, it is no more to be confounded with the equator of rotation than the magnetic poles with the extremities of the planetary axis. It follows a curved line which cuts the terrestrial equator to the east of the Carolinas, traverses the islands of Sunda, Hindoostan, Ethiopia, and Soudan, then passes to the south of the equinoctial line not far from the island of St. Thomas, and lies in America above Brazil and Peru. We may say generally that the magnetic equator curves towards the north in the continents of the Old World and towards the south in the New World. At the present time this line is slowly moving its points of intersection of the terrestrial equator from east to west.

The two magnetic poles occupy in relation to the earth's axis a position quite oblique, since one is situated in the American polar archipelago, while the other is found under the meridian of Australia. It results from this, that the currents are themselves propagated obliquely to the surface of the globe. Instead of advancing in the direction from north to south, the mysterious force moves according

to curves not parallel, which on the Atlantic face of the earth bend towards the west, and on the opposite side for the most part diverge towards the east. The lines of separation between these two zones of western and eastern declination are the only parts of the earth where the compass points directly to the north. In order to indicate clearly the average direction of the magnetic needle for any year whatever in various countries, other lines, called *isogones*, are drawn on the map to the right and left of those marking no declination, where the compass forms one and the same angle with the terrestrial meridian. These curves, connecting all the points of the earth where the mean inclination of the needle remains sensibly equal, are much less regular than the magnetic meridians. Some are directed from the north to the south, others run partly from the east to the west; others again bend in the form of circles and ovals.

At present, the line without declination which traverses the ancient world passes to the east of Spitzbergen, touches Russia in the environs of Archangel, gains the Caspian depression by the valley of the Volga, crosses Persia obliquely, then after having coasted Hindoostan and the islands of Sunda, as if to mark the general outlines of the Asiatic continent, it is directed abruptly towards the southern magnetic pole across the centre of Australia. To the west of this line, as far as the other side of the shores of the continental group which constitutes Europe and Africa, the declination of the compass towards the west increases gradually, and then diminishes above the basin of the Atlantic, and is reduced to zero on the eastern coasts of the New World. The second line without declination, which one might call the American line, descends from the magnetic pole to the west of Hudson's Bay, traverses the great lakes, passes the environs of Philadelphia and Washington, and then curves round the Antilles, as the other line without declination is curved around the archipelago of Sunda, and cuts the extremity of Brazil from the mouths of the Amazon to Rio de Janeiro, and crosses the Atlantic towards the south pole. To the west of this line the deviation of the compass becomes easterly, increasing rapidly above America, then much more slowly across the Pacific, and diminishing to the east of China and Siberia, so as to enclose a kind of magnetic island where the declination is western, as in the basin of the Atlantic. Whatever may be the partial irregularities of these two zones of different variation, it is impossible not to be struck by their general agreement with the most salient features of the planetary surface. The basins of the Atlantic, the Mediterranean, and the Indian Ocean, correspond

with the western declination, and the Pacific corresponds with the eastern declination. Four continents, Asia, Australia, North and South America, belong to this latter zone; while Europe and Africa, form part of the zone of western declination.

During the course of centuries the system of isogonal lines moves very rapidly in certain countries. In the seas of Spitzbergen to the west of the Antilles, in various regions of China, the mean direction of the needle has not varied in a perceptible manner for a century: but it is not the same in western Europe. At Paris at the time of the first regular observations on terrestrial magnetism, the declination of the compass was easterly; it even reached in 1580, 11° 31′ to the east of the meridian. In 1663 the declination existed neither in one direction nor the other, the magnetic needle was directed exactly towards the north. From that time the declination towards the west continued to increase during more than a century and a half, till 1814, when the angle formed by the needle with the terrestrial meridian was not less than 22° 34′. Since then the needle has retrograded towards the meridian, and in the year 1864 the angle was only 18° 30′; the recoil is thus on an average nearly five minutes per year, but it changes in a very irregular manner, for in certain years the western declination has suddenly increased again. We cannot doubt that these secular oscillations of the magnetic current make part of a cycle, the duration of which corresponds with that of some great astronomical phenomena. According to M. Chazallon, this period would be for Paris 488 years, and the magnetic needle would be again directed exactly towards the north in the year 2151. The line without declination moves little by little from the confines of Russia, and will successively traverse Poland, Germany, and France, then passing above the Atlantic, it will later commence its return towards the east. Notwithstanding this secular balance of the magnetic forces, it is probable, however, that as a whole, the currents never end by following exactly the same directions on the surface of the earth: the poles, the equator, the meridians moving incessantly, the network of magnetic lines changes eternally like the relative position of the stars in space.

While this long secular variation is accomplished the needle is ever agitated by oscillations of shorter periods. Those which are completed in the course of a year are evidently connected with the position of the earth relatively to the sun, for its various phases coincide with the equinoxes and the solstices. In western Europe, as Cassini first ascertained, the compass gradually approaches the

meridian, advancing towards the east, during the period which elapses from the equinox of March to the summer solstice; then the magnetic needle again advances towards the west, but slackening its march little by little, it is only at the end of winter that it attains its greatest declination towards the west: the return to the point of departure employs three quarters of a year. In America the progress is different, which doubtless results from the difference of declination. The total extent of the annual variations presents a great irregularity: in 1784 it was about 20 minutes at Paris.

The diurnal variations differ also on all points of the earth. In France, where the amplitude observed oscillates between 5 and 25 minutes, the needle moves from east to west between 8 o'clock in the morning and 1 o'clock in the afternoon; it then returns to the east, and towards 10 o'clock it occupies nearly the same position as in the morning. In countries near the northern pole the extent of the diurnal variations is generally greater than in the temperate zone; in the torrid regions, on the contrary, these variations are slighter, while in the southern lands the diurnal movements become more and more considerable towards the south. As there they occur in the inverse order to those observed in the north, it is probable that the two hemispheres with opposite variations are separated from one another by a line where the compass remains immovable; however, this equator, without variations, has not been yet discovered with certainty, and in all probability would not agree with the magnetic equator.

In the same way as isogonal lines have been traced on the globe to indicate the declination of the compass in different years, so by the *isoclines* succeeding one another on each side of the magnetic equator, those parts of the earth are indicated where the magnetic needle dips towards the ground at the same angle. These isoclinal lines are in general more regular in their curves than the isogonal lines; but they also are influenced by the forms of the continents. It is principally in the northern hemisphere that this difference is shown. Thus the isocline of 50 degrees coasts the shores of Central America, then, after having crossed the basin of the Atlantic, traverses obliquely the depressions of the Sahara, the eastern Mediterranean, the Caspian, and turns northwards round the great mountains of Thibet. The isoclinal line of 70 degrees is developed off the western shores of North America from the peninsula of Alaska to the coasts of the Oregon, while in the Old World it follows the depression formed by the Channel, the North Sea, the Baltic, and

the Gulf of Finland. Finally, the line of 80 degrees follows at a distance the polar shores of America, runs afterwards along the eastern coasts of Labrador and Greenland, and bends in an immense curve round Scandinavia. Like all the other magnetic phenomena, the inclination is subject also to incessant variations, periodical and accidental, but these variations have been less studied than those of declination. At Paris the needle has become less and less inclined since 1671, when it dipped 75 degrees, while in 1864 it was only 66° 3′; the annual diminution has thus been a little more than 3 minutes: observations made at London, and in several other towns of western Europe, lead us to the same result. As to the monthly variations, they are less relatively than those of declination; it is in summer that they have the greatest amplitude.

The isodynamic lines, that is to say, those which unite the points of the earth where the movements of the magnetic needle have an equal intensity, for the greater part resemble in their curves the isoclinal lines; nevertheless they do not coincide with them. The dynamic equator, a line where the intensity of terrestrial magnetism is manifested with the least force, is also inflected in the southern hemisphere, traversing Peru and Brazil, not far from Rio de Ja-

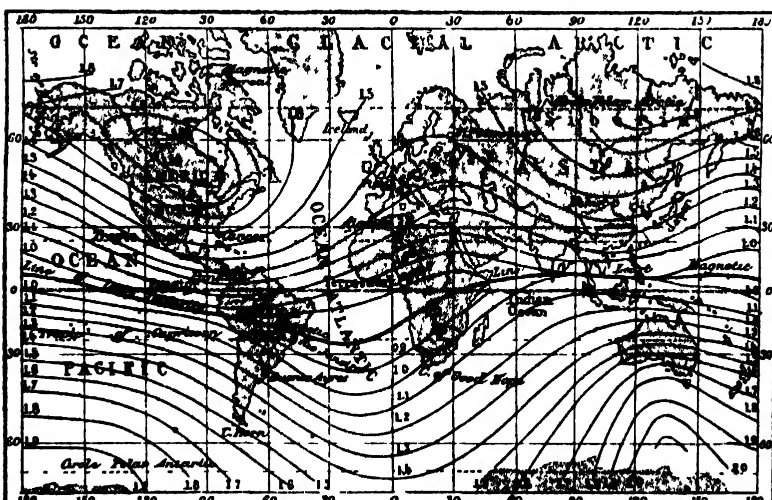
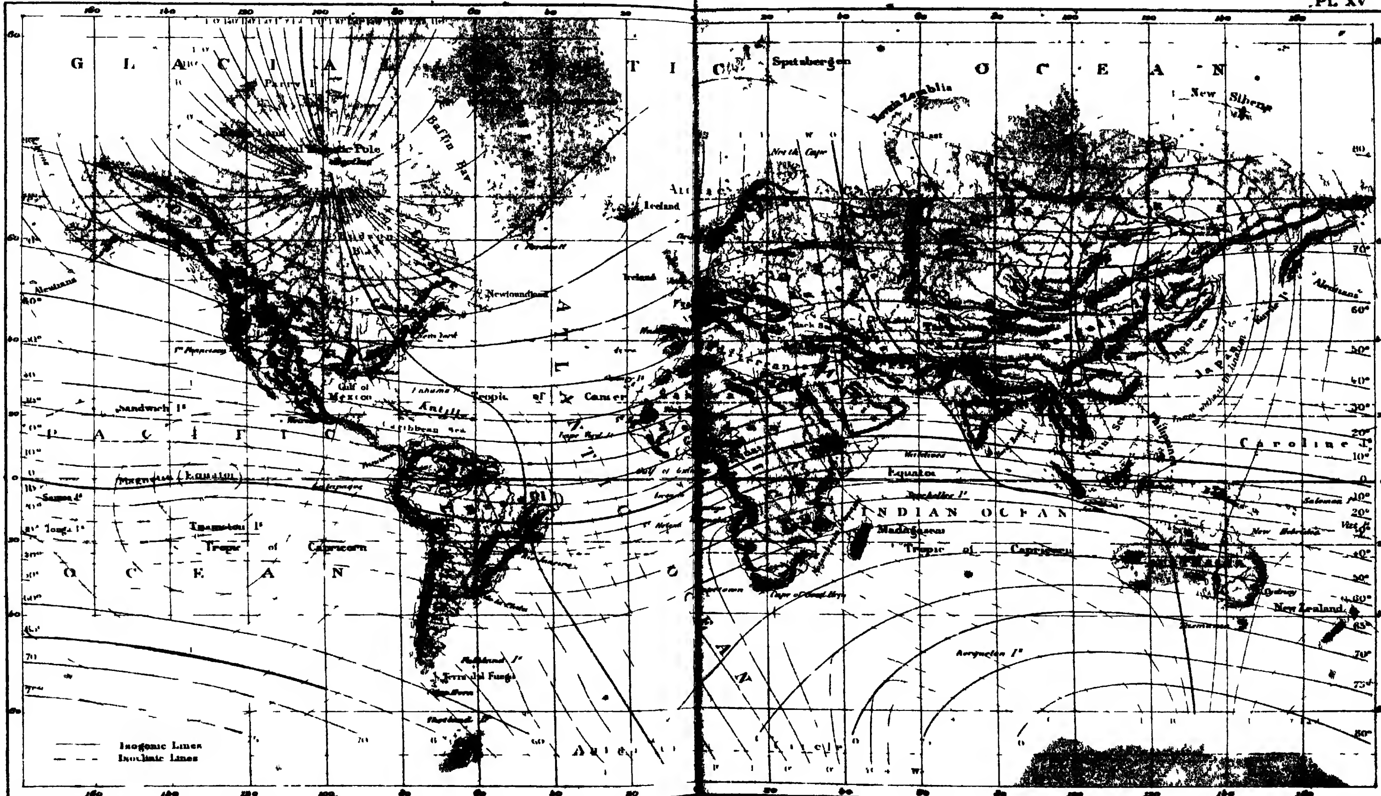


Fig. 149 —Isodynamic Lines.

neiro, and then ascending obliquely by the African continent towards the southern peninsulas of Asia and the archipelago of Sunda;

ISOGONIC & ISOCLINIC LINES.



Engraved by Erhard

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on this equator the movements of the needle are slowest in the Atlantic off the Brazilian coasts. On each side of the line of the least force, the magnetic intensity increases towards the north and south, but in an unequal manner, since the isodynamic line of Florida bends to the north as far as Scandinavia, and that of South Carolina traces the outline of the American shores, and passes into Greenland. In the southern regions there only exists a single dynamic pole, situated at more than 16 degrees from the planetary pole, in the neighbourhood of the icy mountains discovered by Sir James Ross. It is there that the movements of the compass have the most intensity, and they are nearly three times more rapid than in the Brazilian seas. In the north there are two dynamic poles, one to the west of Hudson's Bay, the other to the north of Siberia, not far from the mouths of the Lena. In the same way as the isothermal lines, with which they have besides a great analogy, the lines of equal intensity have their two poles occupying a symmetrical position, the one to the north of the Old World, the other to the north of the New. Thus, as Duperrey remarks, this resemblance of the isothermal and isodynamic lines is a proof of the intimate connection which exists between terrestrial magnetism and temperature.

BOOK V.—CLIMATES.

CHAPTER XXII.

SOLAR HEAT.—IRREGULARITIES OF LOCAL CLIMATES.—EQUALIZATION OF THE TEMPERATURE BELOW THE SURFACE OF THE GROUND.

All the facts of physical geography, the relief of continents and islands, the height and direction of the systems of mountains, the extent of forests, savannahs, and cultivated lands, the width of valleys, the abundance of rivers, the outline of the coasts, the marine currents, winds and all the meteoric phenomena of the atmosphere, vapours, fogs, clouds, rains, lightnings and thunders, magnetic currents, or, as Hippocrates said more briefly, "the places, the waters, and the airs," constitute in their connection with longitude and latitude what is called the climate of a country.

The most important climatic phenomena are those of temperature, for it is to heat that most of them eteoric phenomena, in their various alternations on the surface of continents and seas, are due. It is the overheated regions which put in motion the whole system of atmospheric currents, and it is they too which give to the winds the moisture destined to be dispersed in clouds and to fall far away in snow and rain. By their action on the earth and on the waters the rays of the sun give the first impulse to all that moves on the surface of the globe. It is on this luminous body that the life of our planet depends.

The earth has it is true its own heat, like all bodies in space; but whatever may be the unknown heat of its deeper strata, that of the surface results solely from the great source of heat, the centre of our planetary system. When the sun rises above the horizon the earth is warmed by its rays, but cools during the night by the radiation into space of the heat received during the day. The oscillations of relative heat and cold that we experience from day to night, and from

summer to winter, all depend on the laws regulating the absorption and radiation of heat given off by the sun to the earth, or by the earth into interstellar space. It is these incessant alternations that the thermometer measures, since the heat of the air and the ground vary at all times and in all places, the series of temperatures which succeed each other in various localities, or even in one single place, become, so to say, infinite; and if we wish to keep an account of the phenomena of heat and cold, it is necessary to obtain, by comparison of instruments at regular hours and periods, the averages of diurnal, monthly, and annual temperature. This is one of the most difficult tasks, for we must first remove all possible chances of error, and choose for the place of observation precisely one where the indications of the thermometer are never modified by special causes, such as currents of air or radiated heat. The disturbing influences are so numerous that we are not yet sure of having determined exactly the true average temperature of a city like Paris, where millions of observations have been made. M. Renon even affirms that for a hundred years meteorologists have always given by mistake a temperature too high by almost two degrees Fahr. to the atmosphere of Paris. The use of automatic instruments which trace on paper, either by a pencil or by photography, the continuous series of curves produced by the oscillations of temperature will diminish many probable errors, and singularly facilitate the comparison of all the results obtained in different localities.

If the earth were a globe of perfect regularity, presenting on its surface no contrast of land and sea, plateaux and plains, snow and verdure, and keeping always at the same distance from the sun, a natural distribution of climates would be established over the whole circumference of the earth, and one could exactly measure the degree of heat by the latitude. At the equator the temperature would be at its maximum, and from each side of this line decrease to the poles; thus, as the mathematician Lambert calculated, the total quantity of heat received as 1000 under the equator would not be more than 923 under each tropic and 500 under the polar circle.

But the earth is not an accurate sphere lighted in an always equal manner by the rays of the sun. It is illuminated in a different manner according to the seasons, and the features of its surface, harmonious as they may be as a whole, have not the perfect symmetry of geometrical figures. From this results an infinite variety of climate. One country near the polar circle receives more warmth than another situated at a less distance from the tropics; one region of the

temperate zone is hot in comparison with certain spaces in the equatorial zone. The temperature continually varies, oscillates, and changes under the action of winds, currents, meteoric phenomena, and vegetation; and when indicated by lines on the surface of the earth an inextricable network is formed of which we can only recognize the principal traits. Every season, every day, every minute still adds to the entanglement of these various temperatures, for nowhere do the periodical evolutions of local climates resemble each other in a perfect manner. In mountainous districts especially, the least difference of exposure or height causes the temperature of two neighbouring places to vary as much as if they were separated from each other by hundreds of miles. Beside the wintering towns on the coast-line of Provence and the Maritime Alps, Cannes, Antibes, Villefranche, which are well sheltered by an amphitheatre of hills, the sterile valleys of the Var, the Loup, and the Siagne open, like fractures of the terrestrial crust, making a passage for the terrible mistral, which formerly, they said, contributed more than Marius to chase the Cimbri from Gaul. The various lines of equal temperature which meteorologists have attempted to trace upon maps can never indicate more than general averages, through all the extreme lines moving incessantly from one side to the other like vibrating cords. And if the mean temperature of a single place is so difficult to know in an exact manner, how much more difficult to determine with precision for the whole of a country, the general climate resulting from the combination of all the particular climates.

Numerous observations made in different parts of the earth have demonstrated that the mean temperature, so difficult to ascertain with certainty on the surface, is constant at a variable depth in the earth itself. For as the solid strata composing the exterior of the globe conduct heat but very slowly, neither the solar influence can penetrate far inwards nor the internal heat radiate outwards, wherefore the variations of atmospheric temperature must be gradually diminished, or even entirely obliterated, at a certain distance from the surface. On an average the heat of the day is propagated within the ground so slowly that in nine hours it only traverses the first superficial layer of one foot in thickness. At depths varying from two to five feet all the diurnal variations of heat completely disappear in the temperate zone. The annual variations, much more durable in their effects, penetrate to a greater depth; but in consequence of the earth being so bad a conductor of heat, it is found that at a few yards below the surface the order of the seasons is changed; the summer

heat, so much retarded as it penetrates into the ground, only reaches the layers from 20 to 25 feet deep on the return of winter; on the other hand, the cold does not make itself felt in these depths till the middle of summer. The surface temperature takes no less than a whole month to traverse a layer of earth three feet thick, and in so slow a passage it ever tends to approach the annual average. At Brussels, the maximum heat having been felt on the surface on the 22nd of July, only attained the depth of 26 feet on the 12th of December following, 147 days later; in the same way the interval between the cold on the surface on January 23rd and that of the deep stratum on June 18th was 143 days; while the total annual variation of the temperature, which is about 35 degrees on the surface in this town, is less than 2 degrees at 26 feet below.

The complete neutralization of the influence of the seasons occurs at different depths. In the cellars of the observatory of Paris, situated at 90 feet below the ground, the temperature is constant and is always maintained at 53°. On an average it may be considered that in the north of Europe all the exterior influences of heat and cold have completely disappeared at 78 feet below the surface. The better conductors the underlying beds are, and the more porous they are, allowing air to penetrate from the surface, the greater and more rapid are the penetration and radiation of heat. Experiments made at Edinburgh by Forbes show that carboniferous sandstone is one of the rocks which best conducts heat, for the equilibrium of temperature is only found at a depth of 105 feet. In countries where the annual difference between the heat of summer and cold of winter is very great, it is relatively very low in the ground that we must search for the point where all the annual variations are neutralized. On the other hand, in those countries where the temperature of the various seasons hardly differs, it is only about a foot from the surface that the equalization of the annual temperature is established. M. Boussingault has ascertained that in order to know the annual temperature of New Granada and Ecuador, it is sufficient in certain places to introduce the thermometer from 1½ to 2 feet into the ground. Under the polar climates, where the mean temperature of the atmosphere is below freezing point, the few observations that have been made seem also to establish the fact, that the zone of neutralization of exterior influences is nearer the surface than under temperate climates: in certain parts of New Britain it is said to have a depth of only 9 to 15 feet.* At Yakutsk, where the thermometric average is 12 degrees Fahr., the same tem-

* Studer, *Physikalische Geographie und Geologie*, t. ii.

perature is found at less than 48 feet; below this the ground becomes less cold, owing to the internal heat of the earth; and towards 390 feet the sounding instruments finally arrive at layers of earth which are not frozen.

Springs, like the soil, often show the average temperature of a country, owing to their source in the cavities of the rocks. Indeed, by placing a thermometer in the basins of springs, travellers can ascertain the average climate of the regions through which they pass. Observations of this kind are of great use, but they cannot replace long and patient study of atmospheric heat. One spring is on an average colder than the surrounding air, because its waters are produced by the melting of snows, or arise from rains that fell on the slopes of high mountains; another spring, slightly thermal, has traversed deep channels, where its temperature is raised by the telluric heat; another has passed through fissures which are chilled or warmed by currents of air circulating in the caverns of the mountains. The slight alternations of heat and cold occurring in springs are analogous to those observed in the waters of rivers. Watercourses, always cooler in summer and warmer in winter, have a temperature all the more equal the greater their velocity, because they are subject during less time to the changing atmospheric influences. Thus at Lyons, above the confluence of the two rivers, the fluctua-

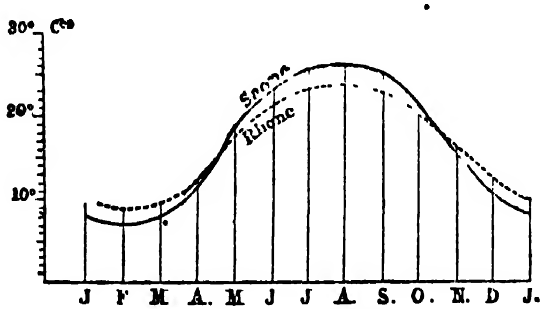


Fig. 150 – Ordinary temperatures of the Saône and the Rhône at Lyons.

tions of temperature during various months of the year are 7 degrees less in the furious Rhône than in the peaceful Saône.

CHAPTER XXIII.

CONTRAST BETWEEN THE CLIMATES OF THE NORTHERN AND SOUTHERN HEMISPHERES, BETWEEN THOSE OF THE EASTERN AND WESTERN SIDES OF CONTINENTS, THOSE OF THE COASTS AND THE INTERIOR OF COUNTRIES, AND OF MOUNTAINS AND PLAINS

ONE of the most important climatic facts is that of the unequal distribution of heat in the two hemispheres. The observations made to the south of the equator during a long series of years are not sufficiently numerous for it to be possible to state a contrast of climate

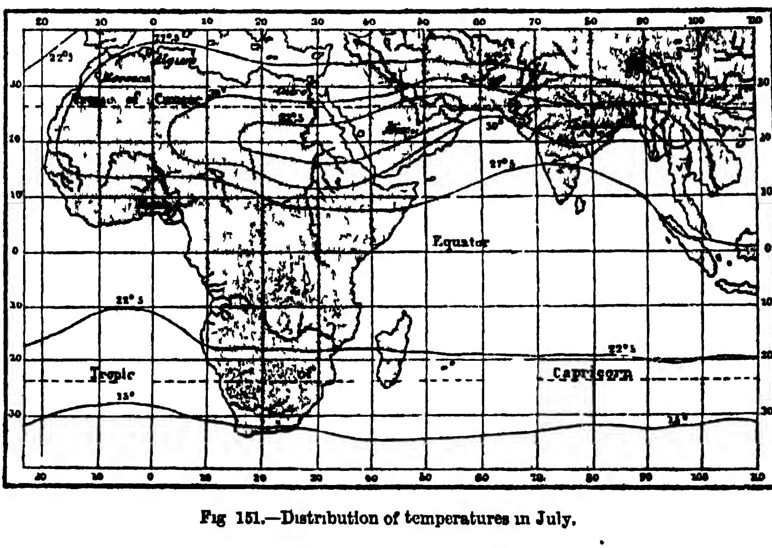


Fig 151.—Distribution of temperatures in July.

for each corresponding latitude of the two halves of the globe. But, taken as a whole, the northern and the southern hemispheres certainly differ in a remarkable way. This is proved by the immense size of the Antarctic ice-fields compared to the dimensions of those to the north, and the long distances traversed by the flotillas of the former in their march towards the equator.* The system of climates like

* See Chap. V. p. 46.

that of winds and currents is drawn towards the north, consequently the line of highest temperature which separates the two hemispheres

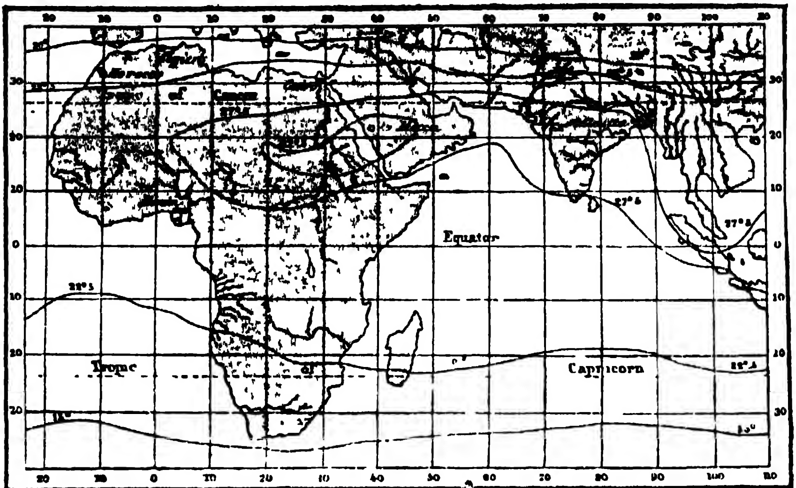


Fig 152.—Distribution of temperatures in October.

is not identical with the equinoctial line, but is thrown more to the north; indeed, the thermal equator of the earth passes through the desert of Sahara towards the twentieth degree of north latitude.

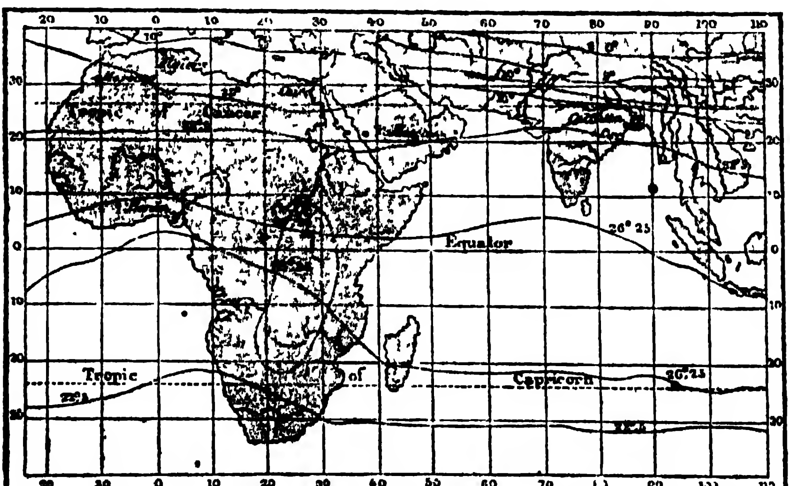


Fig. 153.—Distribution of temperatures in January.

During the spring and autumn, as well as during the summer of the northern hemisphere, the greatest heat makes itself felt not only to the north of the equinoctial line, but also to the north of the 12th degree of latitude.* It is only during the winter of Europe and Asia that the zone of greatest heat occupies the equatorial regions, and even then it is to the north of the equator, in Africa, especially the mouths of the Niger, where the highest temperature is preserved. The disproportion which exists between the continental masses situated to the north of the thermal equator and those which stretch to the south is thus much less than it seems at first.

It is probable that the first cause of this climatic contrast between the continental and the maritime hemisphere is of an astronomical nature, and ought to be sought for in the difference of relief presented by the two halves of the planetary orbit. The spring and summer of the northern regions are longer than the corresponding seasons of the southern countries. It is true that during the warm season of the northern hemisphere the earth is further removed from the sun, and draws nearer to it during the period which is autumn and winter for Europe and Asia. A compensation may therefore be produced in the two hemispheres for the total quantity of heat received, but in consequence of the inclination of the planet on its axis, it is also found that the number of hours of daylight is actually greater than that of the hours of the night to the north of the equator, while to the south it is the hours of the night which predominate. It results from this, that the northern countries receive more heat during the days than they lose by radiation in the nights, and that the inverse phenomenon obtains in the southern regions.† The real result of all these contrasts between the two hemispheres is not yet clearly established, but it is not to be doubted that it constitutes a difference, either periodical or permanent, between the general climates of the two halves of the earth. According to Dove, the mean temperature would be 80° Fahr. at the tenth degree of north latitude, and only 78° at the corresponding south latitude; at the 20th degree the averages would be respectively 77·5° and 74°; at the thirtieth and fortieth degrees of the two hemispheres there would be still a slight difference to the advantage of the northern temperatures. According to Duperrey, there is a difference of about 1·8° in the mean temperature of the two halves of the earth.

Among the secondary causes which must result in rendering the climate of the northern hemisphere a little warmer than that of the

* See figs. 151, 152.

† Adhémar, Lehon.

southern, we must reckon the distribution of rain. Considered in a general manner, the seas of the south are the area of evaporation, the continents of the north that of precipitation. When the water of the Ocean is transformed into vapour, a great quantity of caloric becomes latent, and is borne away with the clouds, the particles of which it dilates; with them it traverses the equator, and is carried away by the counter trade-winds; then, when the latter sink on the temperate regions of Europe and North America, the clouds descend also, and are resolved into snow or rain, when all the latent heat from the Pacific or Indian Oceans, stored up in the vapours, disengages itself and softens the temperature of the air, where it becomes free. Thus by the very fact of their existence, the continents of the northern hemisphere attract to themselves the heat and moisture necessary to the development of the animals and plants inhabiting them; but they also experience greater extremes of temperature than those of the southern hemisphere, where the immense extent of ocean moderates the intense cold and great heat.

If there is a contrast of temperature between the north and south of the world, the opposition is not less marked between the east and west of continents. On the same latitude the coasts of California and Oregon enjoy a much milder climate than those of Japan, Mantchooria, and Nicolajewsk; while in western Europe the atmosphere is as temperate as that of the eastern coasts of North America 20 degrees of latitude nearer the equator.

The causes which thus soften the climate of the western shores in the two great continental masses of the north are due undoubtedly to the atmospheric and marine currents. The northern Atlantic and Pacific have each their Gulf-stream, and winds from the south-west, and these two superposed currents constantly discharge their warmth on the shores washed by their waves. Europe is especially favoured in this respect: not only is it warmed on the west by currents of water and counter-trade winds coming from the equator, but owing to the larger extent of water to the north of the continent, from the tropical seas having a great coast-line washed by the waves; it is less chilled by the polar winds than North America, whose seas are blocked by snowy islands. Whilst Labrador and Hudson's Bay Territory have a soil that is frozen to a great depth, Northern Europe projects its islands and peninsulas into water incessantly renewed by the tepid currents from the south, and its inland seas open like so many reservoirs to maintain to the centre of the continent a temperature equal to that of the outer shores. Nor is

this all.: immediately to the south of Mauritania extends the immense furnace of the Sahara, which warms by its winds the countries of Europe and western Asia. Thus in respect of climate Europe enjoys a special privilege. The north, the west, and the south all aid in the task of raising the mean temperature, and during summer all the surrounding seas store up heat to exhale it gradually during the winter. The east, however, sometimes sends its dry winds, very hot in summer, and intensely cold in winter; but the Scandinavian mountains, the Sudètes, the Carpathians, and the Alps, rise like barriers across the path of these winds, and shelter western Europe. We may form an idea of the influence of the winds on the climates

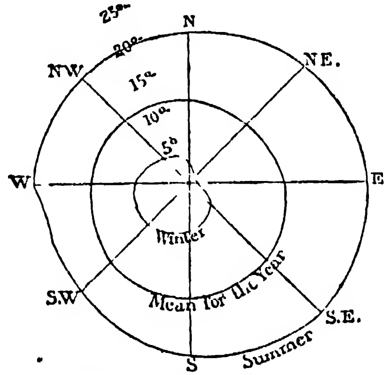


Fig 154.—Variation of the temperature at Paris, during the prevalence of different winds; after Mahlmann and Lalanne

of France and England by the accompanying figure; while occasionally the north-east winds raise the summer temperature of Paris, and depress that of winter almost to freezing-point; the winds from the south-west equalize the climate, bringing freshness during the warm season and heat during the cold.

Another great climatic contrast is that presented by the sea-shore, and the regions situated in the interior of continents under the same latitude. In consequence of the incessant mingling of its waters, the sea equalizes temperatures; into the polar regions it pours the warm waters from the equator, under the tropics it receives the afflux of the polar currents; the revolution of its waves bringing coolness to the burning zones, and carrying warmth to the region of snows. Owing to its mobility the sea has, so to speak, no degrees of latitude; it mixes climates, diminishes the extremes of heat and cold on the shores which it bathes, maintains in the march of the seasons a pace

much more gently graduated than it is in countries remote from the Ocean. To countries which would be subject to polar cold if they were not situated on the border of the waves, the sea imparts the warmth of the temperate zone; it prolongs spring into summer, and autumn into winter. The intense cold and overwhelming heat to which one is subjected in the interior of continents are completely unknown in the open sea; no traveller has yet observed any oceanic temperature above 88 degrees.* We may judge of the moderating influence of the sea by the comparison of two cities situated nearly in the same latitude, one in the interior of the continent, and the other on the shores of the ocean, such as Plymouth, bathed by the mild vapours of the Channel, and Warsaw, placed

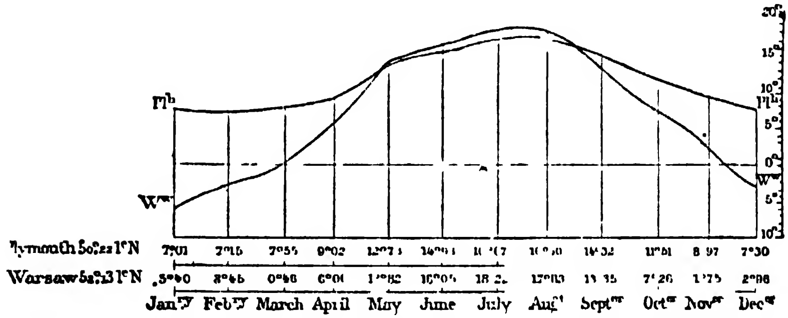


Fig 155 – Continental climate of Warsaw, and oceanic climate of Plymouth.

nearly in the centre of the continent of Europe. M. Emmanuel Liais, who has deeply studied this question, has taken as an example two places much nearer to one another,—Paris and Cherbourg. Though this latter town is nearly one degree of latitude more to the north than Paris, its mean temperature is notwithstanding higher: it is 52·3°, that of Paris being only 51·3°. The difference is much greater between the winter climates of the two cities, for during a series of nine years the mean temperature of the three winter months was 44° at Cherbourg, and 38° at Paris. The contrast between the winter temperature of the two localities is all the stronger the intenser the cold at Paris, for it is precisely then that the relatively warm waters of the sea exercise their greatest influence in softening the climate on the coast. On the other hand, the sea lowers the tem-perature of Cherbourg, for in summer the warmest month is cooler by 2·6° than Paris. In short, the six months from October to March are warmer, while the six months from April to September are cooler.

* Kamtz, *Meteorologie.*

The greatest difference between the highest and lowest annual temperature was 78° at Paris during the four years which elapsed from 1848 to 1852; at Cherbourg it was only 66° during the same period. This difference between the climates of the coasts of Cotentin and the valley of the Seine produces a corresponding difference between the vegetation of the two districts. In the environs of Cherbourg fig-trees, laurels, myrtles, and a great number of other species of trees and shrubs, which would perish in the neighbourhood of Paris, are very luxuriant. It is the same on all the coasts of Brittany, and especially at Roscoff, where an enormous fig-tree is to be seen, one of the most magnificent of the wonders of the vegetable world.

The contrast is greater still between islands surrounded by a comparatively warm sea like Ireland and Great Britain and the regions entirely continental, situated, like the steppes of Tartary or the plateaux of Central Asia, at more than 600 miles from the shores of the Ocean. While in Ireland, which is bathed by the waters of the Gulf-stream, a temperature comparatively cool in summer and warm in winter preserves a constant vegetation transforming it into the "emerald isle of the seas;" the steppes of the Bashkirs, lying under the same latitude, are by turns burnt up by the heat and frozen by the cold; and all vegetation there is impoverished. In the environs of Astrakhan, which is at the same distance from the equator as the vineyards of the Charente, the grapes yield excellent wine, owing to the great heat of summer, but have to be buried in winter to escape the fatal action of the cold.

The other climatic contrasts observed in different countries at the same latitude result from the variety of surface and soil. High mountains change the normal temperature of a country either by arresting or turning aside warm or cold winds, or by lowering the temperature of the atmosphere and depriving it of the moisture which it contained. Forests have also their action. They shelter the ground against the rays of the sun, and when the heat received by the earth returns into space, their interlacing branches are an immense obstacle to radiation. The general influence which they exercise on climate is moderating just as that of the sea: they assimilate extremes by cooling the summer and warming the winter, in the same way that a moist and marshy soil receives heat more slowly than arid lands or sandy tracts, but also retains it with more tenacity. Each exterior feature of the planet modifies the local climate and distinguishes it from that of every surrounding district in its diurnal, monthly, annual, and secular oscillations.

CHAPTER XXIV.

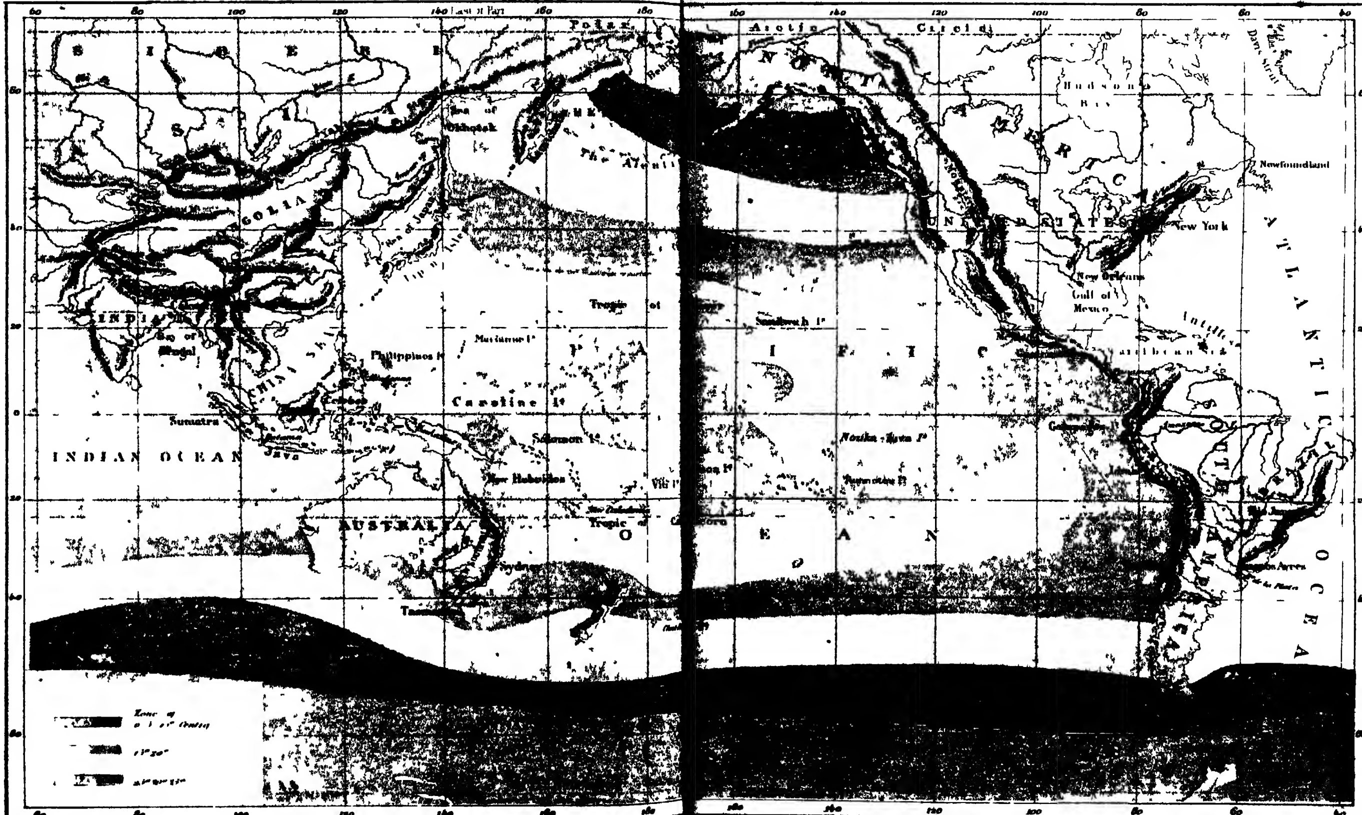
ISOTHERMAL LINES.—THERMAL EQUATOR.—POLES OF COLD.—INCREASE OF TEMPERATURE TOWARDS THE POLES.—OPEN SEAS.

Fifty years ago Humboldt first conceived the idea of uniting by lines all parts of the earth, having the same annual average temperature. These imaginary lines, traced on the circumference of the globe, are called *isothermals*; they give the thermal latitude, which differs widely from the geometrical latitude. While the lines of degrees traced every 69½ miles parallel to the equator are of a perfect regularity and correspond to other imaginary lines traced by astronomers on the skies, the isothermals are contorted in numerous sinuosities of different forms in all parts of the earth. The various causes which modify the temperature of a place, and consequently curve the isothermal lines towards the pole or the equator, have been enumerated with the greatest care by Humboldt. Next to latitude, the principal causes known* are the direction of the atmospheric and marine currents, the elevation above the sea-level, the arrangement of mountain-chains, the outline of the coasts, their relation to the neighbouring seas, the nature of the soil and vegetation.

The thermal equator, that is to say, the curve of the greatest average heat on each side of which the temperature gradually diminishes towards the poles, lies almost entirely in the northern hemisphere, which is warmer than the southern. According to the observations of meteorologists, this line traverses America near the isthmus of Panama, at the point of junction of the two continents, then runs along the coasts of Columbia, Venezuela, and Guiana, to the embouchure of the Amazons, and there bends slightly to the south of the equator. Over the Atlantic the curve of the greatest heat ascends obliquely towards the African continent and the Sahara, the hottest region of the whole world. The precise direction taken by the thermal equator is not yet known either in this burning country or in the Arabian desert, or over the coast of the Indian

* See above, p. 66.

ISOTHERMAL LINES OF THE PACIFIC



Engraved by Erhard

Drawn by A. Vuillemin after Ch. Wilkes

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peninsula: it is only certain that in traversing the *Old World* it continues to keep north of the equinoctial line. In the sea of Sunda and the Pacific Ocean it bends again to the south, and perhaps penetrates into the southern hemisphere at various points. Seeing the want of continuous thermometrical observations over a long period of time, the thermal equator can only as yet be traced on the maps in a provisional manner: it is simply an approximation that subsequent researches will bring nearer and nearer to the truth.

Over various points of this line of greatest heat the temperature is far from being the same everywhere. Above the Ocean it is from 77° to 79°; on the coasts of Columbia and Guiana it is 81° on an average; at Calcutta it attains 82·5°; at the mouths of the Niger it is much greater (85·3°), and undoubtedly in many parts of the interior of Africa and Arabia never reached by refreshing breezes from the sea the mean temperature of the year is still higher. Thus the tracts where this exceptional heat prevails form on the course of the thermal equator a sort of island, the outlines of which wander according to the differences of relief on the surface and the atmospheric phenomena. The researches of Mahlmann have proved that islands of less heat exist in the tropical zone, and that the thermal equator sometimes bifurcates and encloses colder regions.

The sinuosities of the isothermals properly so called are caused over all the terrestrial circumference by these isothermal islands of a higher or lower temperature. In the southern hemisphere, where the continents are diminished gradually towards the south, and where the moderating influence of the Ocean tends to eliminate all climatic differences, the lines of equal annual temperature seem to be pretty regular, and in the Antarctic Ocean they may be considered parallel to the degrees of latitude. The most marked curves of these isothermals of the south are those which are developed immediately to the West of Africa and South America under the influence of the currents of cold water which flow towards the equator along the coasts of these two continents.

In the northern hemisphere the sinuosities of the isothermal lines are much more marked than those in the southern, and cut the degrees of latitude at all angles. Considered in a general manner, the isothermal lines of the northern hemisphere have the form of a double wave, the crests of which rise above the western shores of Europe, and towards those of California, while the depressions coincide with the eastern coasts of the Old and New World.* The highest isother-

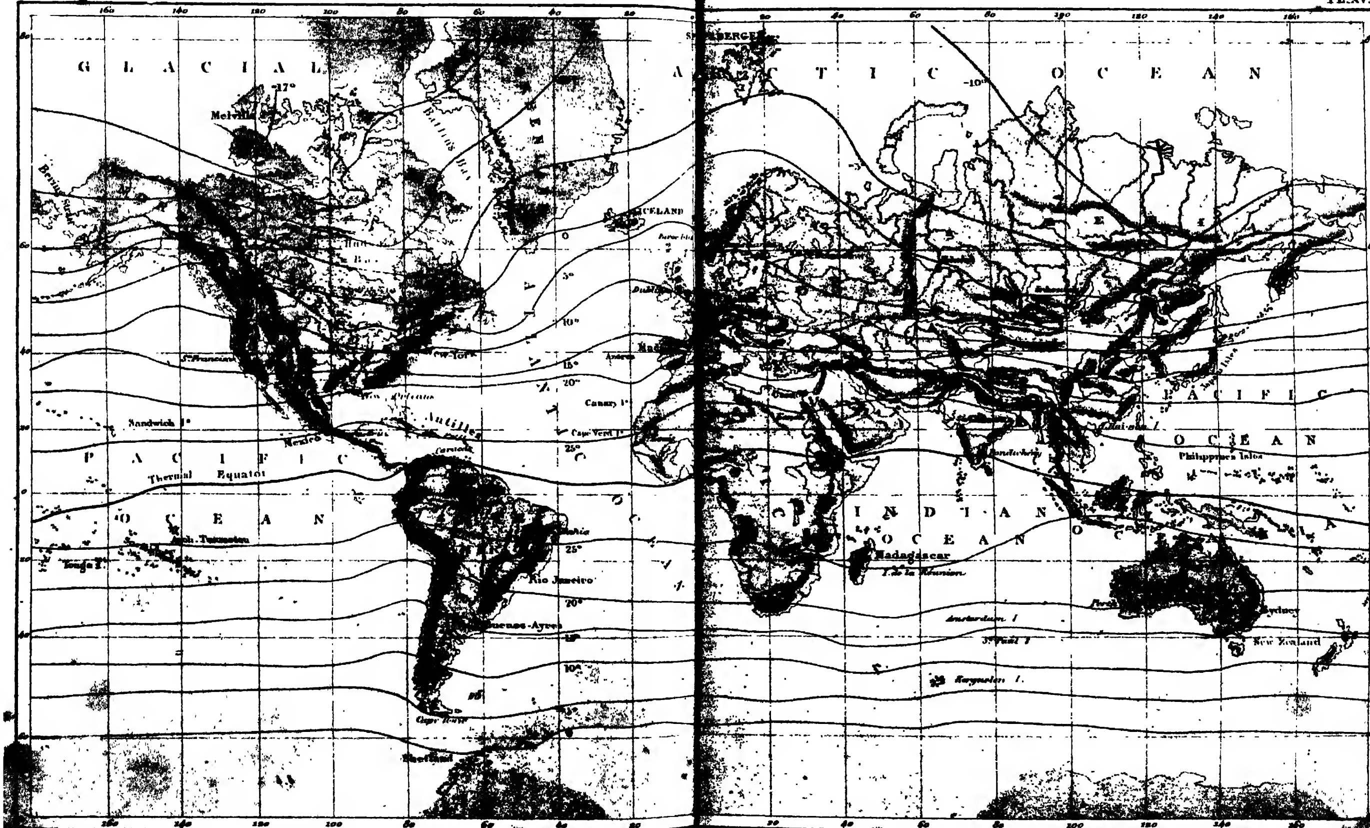
* See Chap VIII. p. 71.

mal wave is that which rises off the coast of New England, Newfoundland, and Ireland, the culminating point of which is found to the north of the British Islands; one would say that it was traced over the Gulf-stream, and in fact it is this current of warm water which drives the whole system of isotherms towards the north. The line of 59° Fahr. which passes over the coast of North Carolina, near Cape Hatteras, cuts the south of France from Bayonne to Montpellier at 9 degrees latitude further to the north. Between New York and Dublin, where the mean temperature is the same (50°), the difference of latitude is 13°, it is 16° or nearly 1100 miles between Quebec and Trondhjem, where the isotherm of 39·2° passes. And the difference is still greater for the line of freezing-point.

Whatever may be the sinuosities of the lines of equal temperature, they all indicate a more or less rapid decrease of heat between the equator and the two polar zones. In the northern hemisphere it has been possible to trace approximately the various isothermal lines as far as that which gives an average temperature of 5 degrees, but beyond this observations have been too rare for it to be possible to mark lines, the course of which is not almost entirely hypothetical; the general direction, however, of the curves renders it very probable that in the polar circle there exist at least two isothermal islands of cold corresponding to the two isothermal islands of heat which are found in the neighbourhood of the equator. According to Brewster, there are in the Frozen Ocean of the north two of these regions of greatest cold, real meteorological poles moving incessantly according to the alternations of the seasons, but in all their oscillations keeping themselves at several hundred miles distant from the geometrical pole. One of these poles of cold is found to the north of the Asiatic continent not far from the archipelago, known under the name of New Siberia, and its average temperature is about 1·5°. The American pole oscillates in the midst of the western islands of the polar archipelago, and the average there is more than 2° below zero. The researches of Muhry have rendered it very probable that in the Antarctic hemisphere there also exist two poles of cold.* The regions whose climate is most severe would thus be situated under latitudes which man has already visited, and consequently the poles probably so called would not be that formidable citadel of ice that geographers once imagined. It is erroneous to believe in the existence of an ice-field all round the pole gradually thickening towards the centre; and erroneous to picture to oneself the two extremities

* *Zeitschrift für Meteorologie von Jelinek*, 1867.

ISOTHERMAL LINES.



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of the terrestrial axis as for ever inapproachable, because of the intensity of the cold.

Besides, the calculations of the mathematician Plana tend to make us believe that the total quantity of heat received increases gradually from the polar circle to the central depression of the Arctic zone. According to the researches made a long time since by the mathematician Lambert, it was thought that the total insolation at the equator being taken as 700 it would be no more than 646 at the tropic of Cancer, 516 at the 45° of latitude, 350 at the Arctic circle, and that at the pole itself it would be represented by the much lower number of 287. In consequence of elements neglected in these calculations, it is found, on the contrary, that the mean temperature, after having gradually decreased from the tropics to the limits of the glacial zone, afterwards rises in a normal manner as far as the pole, which would thus be, at least theoretically, the warmest point of all the polar region, the cold being less severe at the North Pole than it is on the coast of North America and Siberia at 1600 miles further to the south. However it may be, it is certain that during the six months of summer the insolation is greater at the pole than at any other part of the Arctic zone, for, according to the expression of M. Gustave Lambert, "it is always noon" during the summer of the pole because of the position of the earth relatively to the sun. According to calculations made by Halley, nearly two centuries ago, the summer mean must increase from the 60° of latitude to the North Pole in the proportion of 9 to 10.

The experience of polar navigators has fully confirmed the results of the theory, according to which the series of Arctic isothermals would mark a gradual increase of temperature. On his celebrated voyage of 1827 Parry ventured with his bold companions on the great ice-field, which extended to the north of Spitzbergen. Imagining that this field was a real continent of ice, he hastened to cross these polar regions as if they were the frozen steppes of Siberia; but as the sledges advanced towards the north, the ice-field became lighter and more fissured. It was floating to the south, carried along by a drifting current, and before the travellers, on the side next the pole they so much desired to approach, stretched an open sea where floated only a few scattered pieces of ice. At the extreme point of his perilous expedition towards the north, Kane also discovered an immense sheet of water completely free from ice, and that immediately to the north of Smith's Strait, where the mingled fragments of glaciers and ice-fields form a labyrinth difficult to traverse. To the north of the

coasts of Siberia, all encumbered with "toroses," Wrangell and other navigators have also ascertained the existence of an open sea to which they have given the name of Polynia. Finally, in the Antarctic hemisphere, Sir James Ross found tracts relatively free from ice beyond that high wall through which he had to make his way with so much difficulty. Thus it may be admitted as probable that there does not exist a region of unbroken ice at the two extremities of the earth, but rather an open sea with a relatively elevated temperature, and surrounded on all sides either by islands and archipelagoes, or by a circular ice-field. The two girdles of northern and southern ice would be, as M. Charles Grad says, the visible representation of the isothermal lines of the lowest temperature, and on each side the severity of the cold would diminish.

CHAPTER XXV.

EXTREMES OF TEMPERATURE.—ISOCHIMENAL AND ISOTHERAL LINES.—DAILY AND MONTHLY VARIATIONS.—DECREASE OF WARMTH IN THE UPPER STRATA OF THE AIR.—VARIATIONS OF CLIMATE DURING THE HISTORICAL PERIOD.

THE total difference observed on various points of the earth between the highest and lowest extremes of temperature much exceeds 300 degrees. Captain Back endured at Fort Reliance, in English America, 70° below zero, which is hardly inferior to that which is believed to prevail in the interplanetary spaces; a Russian traveller observed near Semipalatinsk 72 degrees; still more, Gmelin is said to have experienced (?) at Kiringa, in Siberia, the truly terrible cold of 121° below zero,* while M. Duveyrier, travelling in the country of the Touaregs, saw the thermometric column indicate a warmth of 155·5°. Thus, without taking into account the observation probably erroneous, the series of ascertained temperatures includes from 250 to 260 degrees, and man has certainly to endure frequently extremes of cold and warmth without being able to measure them still greater than those which have been regularly observed. Even on one point of the earth the highest and lowest temperatures in the course of the year often present the enormous difference of more than 144 degrees. In the vast frozen plains of North America, where Back had to endure the severe cold of 70° below zero, Franklin experienced during the long summer day a torrid heat of 87°. Between these two extremes the scale of temperature traversed in the year is about 157 degrees. Not far from the equator the so-called "burning" regions of the Sahara present, according to Duveyrier, a thermometrical difference almost as considerable as that of the polar countries of New England.† This is because, in spite of the difference of latitude, the deserts of Africa and the granitic plains of North America resemble each other by their continental position, and the relative uniformity of their relief. Remote from the Ocean, that great equalizer of climate, and

* Thomson; Sir John Herschel, *Physical Geography*, p. 238.

† See in "*The Earth*" the section entitled, *Plains*.

destitute of high mountain-chains, which could arrest the cold or warm winds blowing from different points of the horizon, these countries must be subject to very abrupt alternations of temperature. How much more equable are climates where the moderating action of marine waters,—as at Surinam, the Canaries, and Madeira,—or else the shelter offered by a rampart of mountains,—as on the coast of the Genoese Alps,—maintaining a temperature whose extremes only differ from 20 to 55 degrees. In France, a country which represents a fair average through a great many of its physical features, the difference between the intensest cold and greatest heat rarely reaches 99 degrees, and in ordinary years does not exceed 81°. During all the series of meteorological observations made at Paris during the last century, the mercury has oscillated in all 110·5°; at Nice the greatest variation has been 78°.

Through this greater or less change in the height of the thermometer in various countries of the world, it results that the lines of equal temperature for each season, and more still for each month, are much more sinuous than the isothermals of the year. The name of *isochimenal* lines is given to those which unite all the localities where the winter temperature oscillates to about the same extent; the *isotheral* lines are the curves drawn through those places which present on an average the same summer temperature. We can also cover maps with *isoeral* lines, or equal temperature in spring, and *isometoporal* lines, or equal temperature in autumn, and *isomenal* lines or curves of average heat for each month in the year might even be drawn across the continents and seas. But meteorological observations not being yet numerous enough for this immense labour to offer all the certainty desired, it is better to limit oneself provisionally to the study of isotheral and isochimenal lines, which have, above all other lines of seasonal or monthly temperature, the advantage of indicating the extreme periods in the alternations of heat.

The direction followed by the isotheral and isochimenal lines in Europe and North America is a singularly striking example of the influence which the unequal distribution of land and sea exercises on climate. In summer, when the northern hemisphere is inclined towards the sun, and receives the greatest quantity of heat, the countries situated in the interior of the continents of the north are much more heated than those bordering on the sea. During the cold season the contrary takes place: the winds and the currents coming from the equatorial zone temper the severity of the cold in the neighbourhood of the coasts, while far into the continents the

tempering influence of the Ocean and the aerial currents of the south make themselves much less felt. Consequently the isotheral lines curve towards the north in the two northern masses of the Old and New World, and bend to the south in traversing the Atlantic and the Pacific; on the other hand, the isochimenal lines bend to the south in their passage across the continents of America, Europe, and Asia, and curve in certain places by more than 600 miles to the north in crossing the sea. The contrast between the curves of the continental climate and those of the oceanic becomes still more striking when we take, in order to oppose them to one another, as Kiepert did, the isothermal lines of January, which is on an average the coldest month, and those of July, which is the warmest. In Great Britain especially this opposition of winter and summer climates is remarkable. The mild influence of the Gulf-stream and the west winds goes even so far (as is shown by one half of Fig. 156)

Isochimenal Lines | Isotheral Lines.

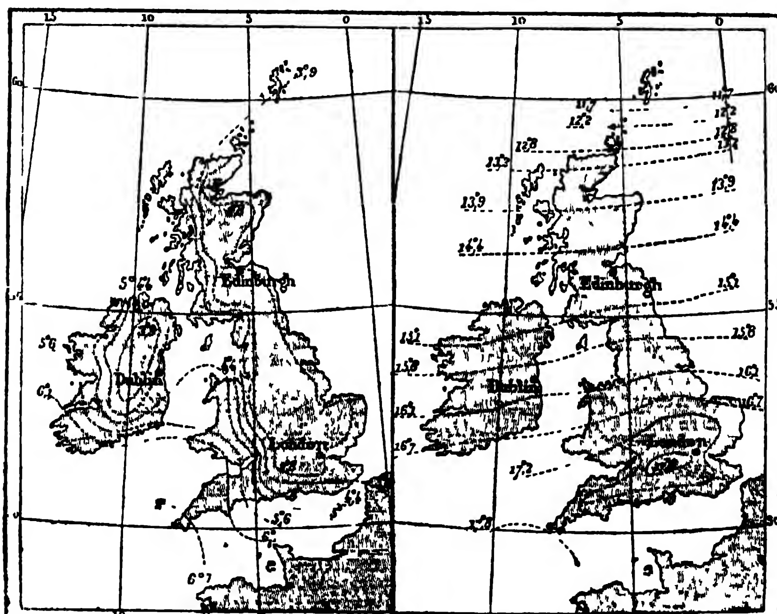


Fig. 156.—Climate of the British Isles.

as completely to lead back the isochimenal lines, which are thus

developed from the south to north, instead of running from west to east parallel to the degrees of latitude.

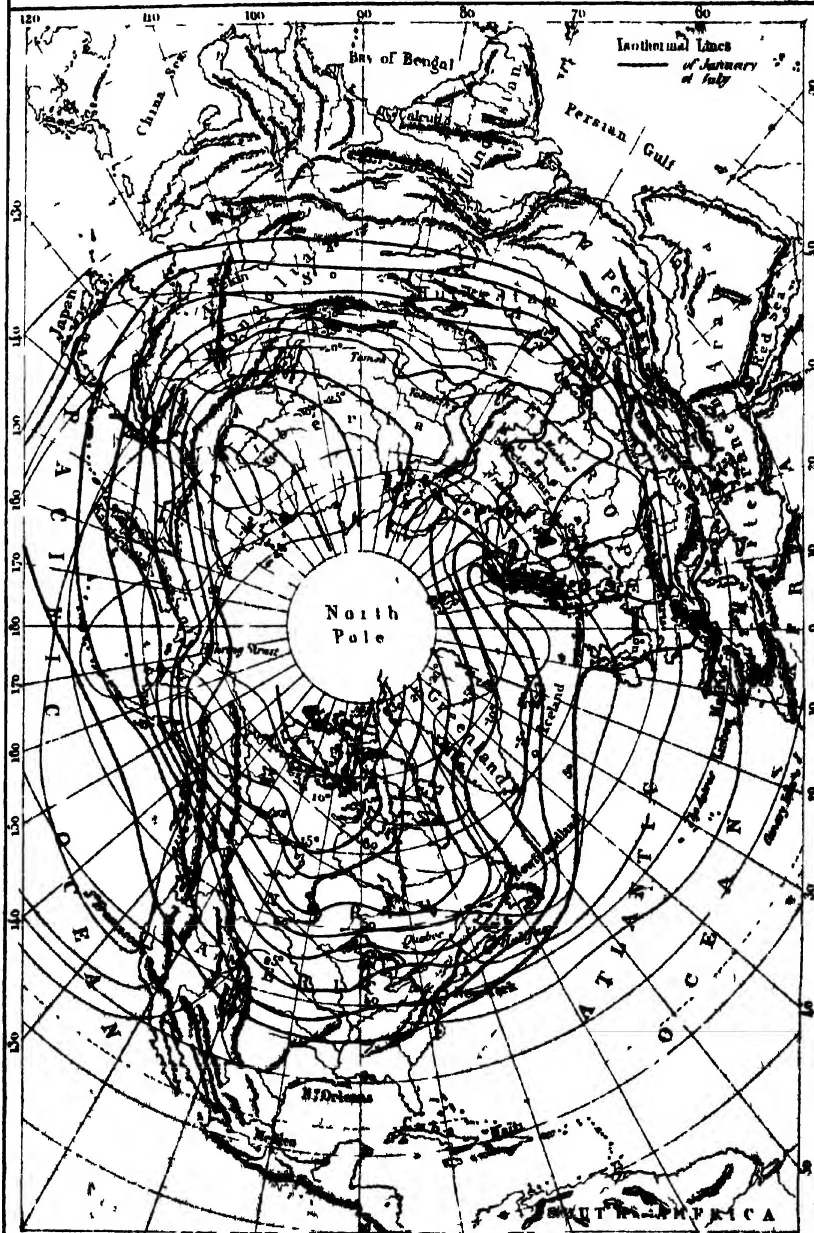
We can understand the decided influence which these inequalities, with their alternations of warmth in countries having in other respects the same mean temperature, must exercise on plants and animals. One kind, which can well support the severity of winter without dreading the heats of summer, is propagated over vast regions in the interior of continents; another kind, which shrinks from the low winter temperatures, when remote from the sea-shore, does not pass latitudes which it crosses by several degrees in the neighbourhood of the Ocean. Thus the elk lives in the peninsula of Scandinavia, which is bathed by the tepid waters of the Gulf-stream, at 700 miles further north than in Siberia, with its extremes of heat and cold.*

The course of the various isothermal lines depends in great part simply on probabilities, since between all the points whose temperature has been observed during a longer or shorter period of years, or only months, there remain here and there wide intervals where no thermometrical notes have yet been made. There are uncertain spaces through which meteorologists cannot draw lines of equal temperature, inasmuch as they have no series of precise observations on which to base them. Thousands of persons in the United States, Canada, the Antilles, Hindoostan, and South Africa, have joined their efforts to those of all the official savants to note down the innumerable oscillations of heat and cold, which by their grouping may reveal the laws of temperature. Day after day they ascertain the horary variations which afterwards allow them to establish the mean heat of the day, month, and year, and then to compare the place whose condition they have studied with other localities where the alternations of heat and cold succeed each other in a more or less analogous manner.

From millions of horary variations which have been observed for a century in various parts of the world, it results that the greatest heat of the day makes itself felt, on an average, between one and two o'clock in the afternoon, while the lowest temperature precedes sunrise by an hour, or even half-an-hour. It is easy to understand why the extremes of heat and cold do not coincide exactly with midday and midnight. After midday hour, when the sun again begins to incline towards the horizon, its rays continue to heat the ground and the atmosphere; it is only later that the loss of warmth

* See the two following books.

ISOTHERMAL LINES OF JANUARY & JULY IN THE NORTHERN HEMISPHERE.



Drawn by A. Vuillemin after H. Kiepert Engraved by Erhard

CHAPMAN & HALL LONDON

caused by radiation equals, and then exceeds, what is gained, and the temperature begins to sink. During the night the contrary phenomena occur; the earth and the atmosphere which surrounds grow colder till dawn announces the near appearance of the sun, and the nocturnal radiation is compensated for by the increasing heat of the new day. In the island of Java the diurnal heat attains its maximum a few minutes after one o'clock in the afternoon, and is, on an average, found at its minimum a little before six o'clock in the morning. At Paris, according to the observations of Bouvard, the highest temperature (58°) makes itself felt at two o'clock in the afternoon, the lowest (45°) falls at four o'clock in the morning, and the mean heat of the day, which is at the same time that of the year (51·2), returns at the corresponding periods of 8.20 in the morning and the same hour in the evening.

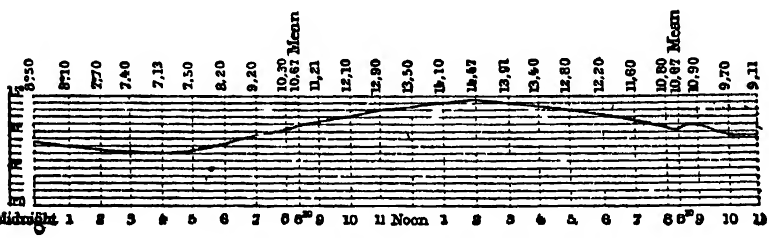


Fig 157.—Diurnal variations in the mean temperature at Paris.

The monthly variations present in their regular oscillations the same phenomena as the hourly ones. It is not at the solstice of June that the northern hemisphere enjoys the greatest quantity of heat, and it is not at the solstice of December that it is subject to the severest cold. After the sun has ceased to illuminate from the zenith countries situated beneath the tropic of Cançer, the heat still augments till July and even till August in a great many regions situated towards the north pole, and in mountainous countries. On the other hand, the greatest cold of the northern hemisphere continues and is even aggravated when the solar rays already bring an increasing quantity of heat. In Europe and North America it is the month of January that is ordinarily the coldest; and there are even some towns, like Palermo, Gibraltar, and New Orleans, where the lowest temperature of the year falls in February, hardly a month before the vernal equinox.

In the neighbourhood of the equator, illuminated by a vertical sun, the monthly variations of temperature are much less important than

in countries situated beyond the tropics, and they depend much more on the direction of the winds and the alternation of rains and droughts, than on the position of the sun in the ecliptic. Thus at Singapore

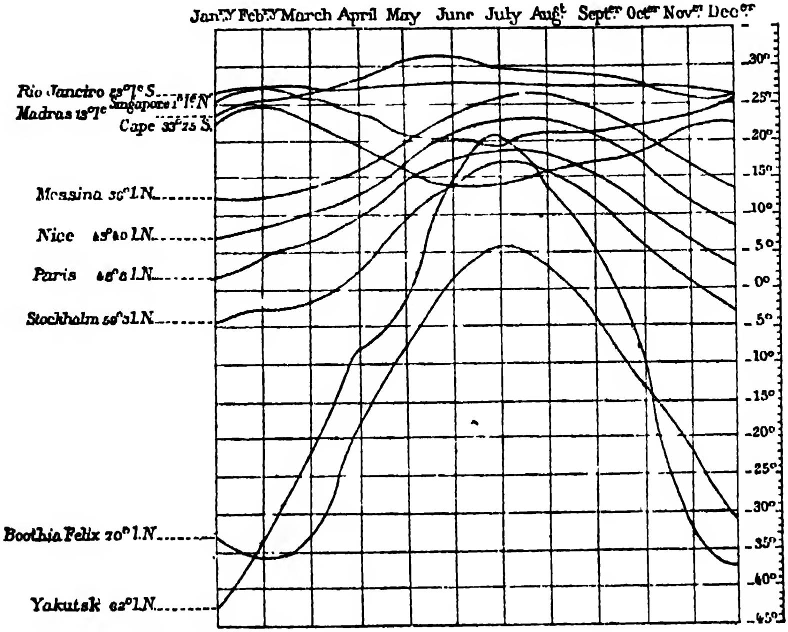


Fig. 158.—Monthly variations of the temperature in various places.

the total difference between the coldest and hottest month is scarcely 3·5 degrees. To the south of the equinoctial line the monthly variations become more and more considerable, but in the reverse order to that ascertained in the northern hemisphere. It results from the researches of Dove that, taking the average of all the temperatures over the whole world, the month of July is the hottest of all the year.

In order to account for the average variation of cold and heat from month to month, and at different hours of the day, meteorologists have had the ingenious notion of drawing curves which, by their deviation from the central point, taken as zero, indicate the hourly temperature for every month of the year. We give as example of these diagrams a figure which enables one to read the temperature of various hours at Brussels during all the cycle of a year. Another very elegant figure (Fig. 160), drawn by M. Leon Salanne, after the data of

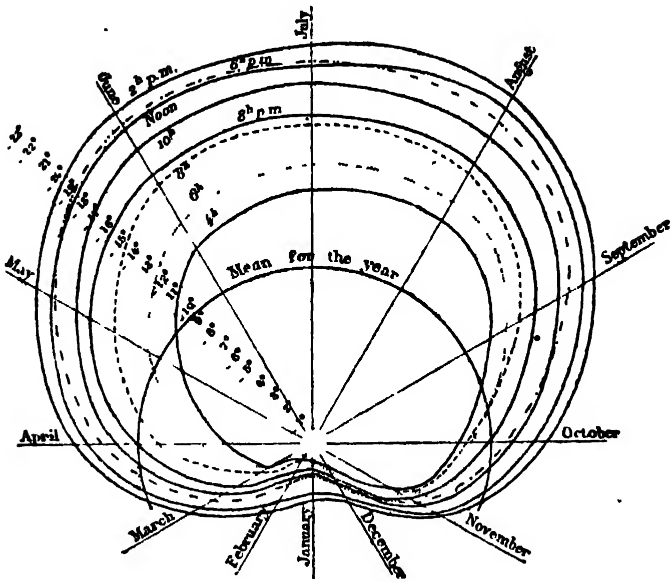


Fig. 159.—Temperatures of the same hours in different months, at Brussels. after Quételet.

Kamtz, represents the thermometrical curves at all hours of the day according to the month: it is the meeting-point of the horizontal and

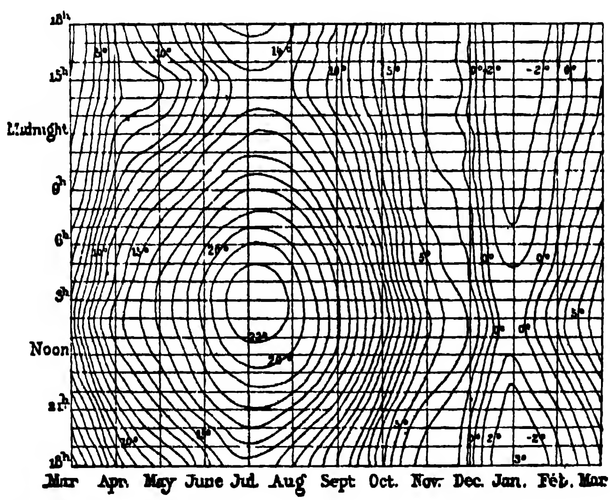


Fig. 160.—Variation of the mean monthly temperature, in the same hours: at Halle.

vertical lines which indicates the degree of heat. Thus, as is seen by figure 161, constructed with the same elements, the difference of

Fig 101.—Temperature of the different hours at Halle.

temperature between day and night is much greater in summer than in winter. Besides, the curves show clearly that the long summer is followed by a short one called "St Martin's summer," and that a return of cold is generally felt in May.

Above the surface of the ground meteorologists observe in the atmospheric strata a decrease of temperature similar to that which takes place between the torrid and the frigid zone. The rarefied air of the upper regions must necessarily be chilled the nearer it approaches to the cold interplanetary spaces, and loses the watery vapour which serves as a screen for the nocturnal radiation of heat. Nevertheless, it is seldom that the temperature falls in a perfectly regular manner from the surface of the ground and the ocean to the heights of the atmosphere, for winds, clouds, and other meteoric phenomena incessantly modify the condition of the aerial strata, and frequently those which rise on the sides of a mountain penetrate from a relatively cold zone to a more elevated temperature. The order of the climates is found reversed. Thus in the winter from 1838-1839 the cold was 4° below zero at Andancette, on the banks of the Rhône, while in the mountains of St Agrève, at 3690 feet higher, it was 10·4 above zero. In the same way Mr. Glaisher ascertained in the night of October 2, 1867, a continuous increase of warmth to the height of 984 feet. In other ascents the same aeronaut had found no appreciable change between the temperature of the ground and that of the atmosphere to the height of 2300 feet.* Besides, M. Prestel has proved, by long and

* Kamtz and Martius, *Meteorologie*, p. 200; Marie Davy, *Les Mouvement de l'Atmosphere*, p. 104.

precise observations, that in that portion of the air which rests immediately on the ground the heat increases constantly from below, to at least 30 feet.* In consequence of meteorological perturbations this zone of increasing temperature may sometimes rise to a considerable height above the surface.

Unfortunately, the series of regular observations made at a great height are still very rare; and even in Switzerland, where so many eminent men busy themselves in scientific researches, there only exist two points above 2000 feet, the hospice of St. Bernard and the pass of St. Gothard, where the monthly averages of temperature are ascertained with certainty. It is therefore only in an approximate manner, that we have been able to calculate the laws according to which the heat diminishes in the higher strata of the air during the various seasons. At all events, it is certain that during the summer and in full sunlight, the aerial strata of different temperature are much thinner in proportion than in winter and during the night. One could say in a general way, with Helmholz, that on the sides of the Swiss mountains the heat diminishes upwards by one degree at intervals of 300 feet in summer and 450 feet in winter; according to M. Charles Martius, the average intervals for the entire year would be from 312 to 315 feet. Other savants have found slightly

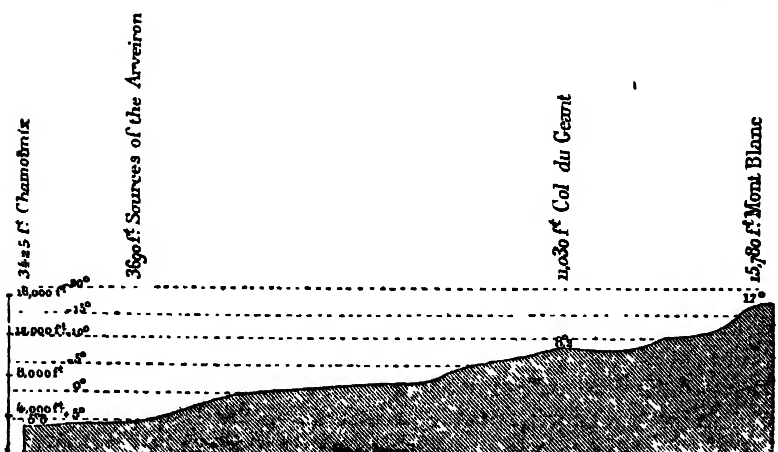


Fig. 162.—Succession of Climates on the slopes of Mont-Blanc.

different figures. Thus de Saussure, to whom the honour belongs of having first made observations of this kind, ascertained that on the

* *Zeitschrift für Meteorologie von Jelinek*, Jan. 1, 1867.

western slopes of Mont Blanc the decrease of temperature during the warm season was about one degree for 300 feet. However, each mountain differs in this respect, and on isolated peaks like le Ventoux the superimposed climates are much closer to each other than on the sides of heights which form part of vast mountain systems.

Studer estimates the average height of the isothermal line of 50 degrees in the Alpine masses, at 1300 feet high; the line of 41 degrees would rest at 4200 feet above the sea-level; that of 32 degrees would surround the mountains at 7200 feet, and the temperature would continue thus to diminish one degree for every 300 feet to the summits. Thus in the maps which represent the relief of the mountains by concentric curves of level, these curves may serve to illustrate not only the increase of altitude, but at the same time the fall of the average temperature; they are like superimposed degrees of latitude. Further, the observations of aeronauts have rendered it probable that in the upper regions of the atmosphere the interval increases more and more for every decrease of one degree in temperature. Beyond the limits of the atmosphere all the heat which the rays of the sun impart to the earth disappears in the cold of space, which is estimated at about 108 degrees below the freezing point, and reigns supreme throughout interstellar space.

The study of the climates which now prevail on the surface of the globe ought to be completed by that of the changes experienced during historical times; unfortunately, the earliest meteorological observations date from an epoch so recent, and the too scanty and very uncertain facts on which we have to depend to arrive at a knowledge of the condition of the temperature in former centuries, do not authorize us to establish a precise law of the modification of climates. Long ago Arago attempted to establish, by very ingenious considerations, that in the space of the last 30 centuries Palestine has continually enjoyed a temperature from 70 to 71 degrees; for now, as in the times of Jewish history, the northern limit of the zone where dates ripen and the southern limit of the vine coincide, on the banks of the Jordan.* Nevertheless, Arago did not refuse to believe that in western Europe the laws regulating the temperature have notably altered; this is proved, he says, by the gradual retrogradation of the vineyards towards the south. In our days the vine is no longer cultivated on the shores of the Bristol Channel, nor in Flanders, nor in Brittany, and in these countries which the chroniclers—perhaps too laudatory—tell us produced exquisite wines,

* *Annales des longitudes*, 1834.

grapes cannot ripen now save in exceptional years. Mr Fuster says that titles of property going back as far as 1561 state, that formerly the vintage took place at heights of 2000 feet on the sides of the mountains of Vivarais, where in the present century the vine no longer bears fruit. In the same way in the environs of Carcassonne the culture of the olive-tree has retrograded from 9 to 10 miles to the south in a hundred years;* the sugar-cane has disappeared from Provence, where it was acclimatized; the orange-trees of Hyères, the cultivation of which extended in the 16th century as far as the village of Cuers, have been struck with disease under a sky that is no longer favourable to them, and have been obliged to be replaced by trees with less delicate fruit, such as peach or almond-trees. Ought we to see, with M. Alphonse de Candolle, in this gradual retreat of the vines, olives, and orange-trees, only a simple economical fact resulting from the greater facilities for commerce, or is it indeed allowable to infer from these facts that the annual temperature, or at least the summer heat, has diminished in France since the Middle Ages? It seems impossible to reply with certainty.

It is known also that in many parts of the Alps tradition speaks of a continuous refrigeration of the mountains.† According to all the botanists who have travelled in the Alps of Savoy and Switzerland, and the Carpathians, the limits of the high pine forests have sunk sensibly on the slopes of the mountains. M. Kerner estimates the retreat of the forest vegetation at over 300 feet in vertical elevation during the last two or three centuries: everywhere are perceived, beyond the present limits of the greater vegetation, the remains of dried-up trunks and half-decayed fragments of immense roots. Perhaps mankind and the animals which accompany them to the high pasture grounds—cows, sheep, and especially goats—are the true authors of this gradual decline of the limit of trees. In the course of centuries the forest has little by little ascended the escarpments and the slopes, the higher trees protecting the smaller ones from the cold with their branches; but if the least attack be made on this battle front either by the axe of man or by the teeth of animals, wind, snow, and avalanches instantly profit by the gap, and the forest begins to descend on the slopes of the mountains. Some botanists attribute this retreat of the pine forests not to the diminution of the annual heat, but to the great inequality of the temperature, to the more sudden alternations of cold and heat, to the frosts

* Bourlot, *Variations de latitude et de climat*, p. 46.

† See in "*The Earth*" the section entitled, *Snow and Glaciers*.

and thaws of the spring. What renders this hypothesis very probable is, that in the plains of Hungary constant encroachments of the plants of the Steppes have been observed in a westerly direction, and yet no movement in the contrary way has been remarked of western species. It is concluded from this that the excessive climates advance gradually towards the west.*

Besides this, direct thermometric observations have proved that for a century the cold has slightly increased at various places in Germany, at Ratisbon, Prague, Hamburg, and Arnstadt; the month of December having become relatively much colder, while January has become notably warmer.† On the other hand, Glaisher has ascertained that the mean temperature of England has increased by 2 degrees in the last hundred years, and for the single month of January the increase of temperature is no less than 3°. In France the extremes have drawn nearer to each other, the climate having become milder and more equable.

Another climatic change seems likewise to be proved: Iceland and eastern Greenland have become much colder since the 14th century, for in the first-named country the large trees have ceased to grow, and on the opposite shores of Greenland a number of valleys, formerly inhabited, have become completely inaccessible in consequence of being invaded by ice. However it may be, we cannot doubt that climates are incessantly modified in a more or less sensible manner over all points of the terrestrial surface, since the physical phenomena, from which the unequal distribution of temperature in part depend, are themselves incessantly changing. The mountains, the mass of which arrests the winds, contribute to the formation of clouds, and attract snow and rain; further, they are lowered little by little by denudation, and their materials serve to fill up the lakes, and to throw long peninsulas out into the sea; rivers change their course, and their volume of water increases or diminishes; marshes are dried up, while others are formed in the midst of plains; continents sink or rise; here archipelagoes show themselves above the Ocean, elsewhere islands are swallowed up; maritime currents and the winds are in a perpetual change. As the fossil remains of earlier faunas and floras attest,‡ strong climatic oscillations have taken place at each period in the history of the earth, and cycles of heat and cold analogous to our annual seasons of winter and summer have succeeded

* Hann, *Zeitschrift fur Meteorologie von Carl Jelinek*, Vol. I. 1867.

† Fritsch, *Zeitschrift fur Meteorologie von Jelinek*, No. 18, 1867.

‡ See in "*The Earth*" the section entitled, *The First Ages*.

each other in the course of ages. Without it being necessary to admit a change of axis and variation of terrestrial latitude, we may affirm that the present epoch, like the past, also presents in its climates a whole series of successive changes, and even history proves that the labours of mankind have a very large share in these very important modifications of the condition of our globe.*

* See below the section entitled, *The Works of Man.*

PART III.—LIFE.

BOOK I.—THE EARTH AND ITS FLORA.

CHAPTER I.

THE ASSEMBLAGE OF LIVING CREATURES —NUMBER OF VEGETABLE SPECIES —PROPORTION OF DICOTYLEDONS, MONOCOTYLEDONS, AND CRYPTOGAMS.—FORESTS AND SAVANNAHS.

From the simple harmony of its forms, the regularity of all its external features, the purity of the air which surrounds it, and the light which colours it, the surface of the planet is, as a whole, of magnificent beauty; but that which lends especial grace and charm to the earth is the infinite number of organisms which people it. It is these which add such a marvellous variety of aspect and such great animation to the cold majesty which the bare face of the rocks presents, such as we still see here and there in desert regions destitute of vegetation. Light, heat, electricity, and magnetism, which give rise to so many changing phenomena in the life-history of the world, develop centres of activity in that world of vegetable and animal life, which the creative force of the elements engenders by a mysterious transformation. Hundreds of millions of different species, composed of innumerable particles, which are continually in a state of transition from the living animal to the earth, and from the earth to the living animal, germinate, grow, and die, to give place in their turn to other numberless generations of organisms. Thus multitudes succeed to multitudes in the immense series of ages. The upper strata of the earth are renewed by all this matter which has lived. The coal-measures, the chalk and the numerous other strata of limestone, which present in many places several miles of thickness, and thus constitute a very important part of the framework of our globe,

are nothing else than the remains of plants and animals that formerly inhabited the land and the ocean. In our days, too, new layers, composed entirely of the remains of organized bodies, are constantly being formed, and almost the whole surface of the land is covered with humus or vegetable soil, formed by the destruction of life, which produces life in its turn.

It is chiefly plants which aid the formation of this nutritious earth, and thus prepare, centuries beforehand, the food of generations to come. In looking to the origin of life, we find certain undecided forms termed by Carus "proto-organisms," which seem to partake at the same time of the nature of the animal and the plant; but on developing they soon exhibit, by their structure and mode of life, the kingdom to which they belong. It is the vegetable kingdom in particular that peoples and embellishes our earth, thanks to the abundance of its species, the richness of its forms and colours, and the vast dimensions of its trees, some of which, like the *Sequoia* and the *Eucalyptus*, rise to more than 300 feet high into the region of the clouds. But how does the planet produce the innumerable living bodies on its surface. from the green conferva, which germinates on ponds, to man, who, proud of his strength, bravely meets his destiny? This is the great problem which excites the attention of the learned, and which is not, perhaps, altogether insoluble. The subject has given rise to much discussion, and to many experiments by chemists and biologists, without at present any definite result being arrived at.

Botanists have not yet had time to count the prodigious number of plants which surround us, from the great oak, with spreading foliage, to the humble lichen spread on the ground like a stain of blood. Besides, if the multitude of the vegetable species have not yet been computed, it must also be said that they are not yet agreed on the definition of species, some seeing simply varieties, where others find absolutely distinct characters. A century ago Linnæus knew only 6000 species; the lists have since gradually increased in proportion as the various regions of the earth have been more and more explored, and now the total number of plants contained in the herbaria is estimated at about 12,000;* the increase has thus been, on an average, about a thousand each year. As to the numerous species which botanists have not yet classified, nor even discovered, we can only judge by proportion of the probable figure. It is thus that M. Alphonse de Candolle has been able to fix, in a general

* Charles Martins, *Du Spitzberg au Sahara*, p 17.

manner, the number of 400,000 to 500,000 species (250,000 being phanerogams), for the whole of the terrestrial flora. Up to our days, therefore, hardly a quarter of our riches has been recognized in the great inventory of the vegetable productions of the globe. And not a year passes without important discoveries being made by travellers in different parts of the world. Even the best known countries of Europe, which botanists have not ceased to explore for a century, present every year new species to fortunate collectors of plants.

Of the number of classified species already so considerable, the greatest part, or about two-thirds, is composed of dicotyledonous phanerogams, that is to say, of plants with visible flowers, and springing from the ground with at least two primordial leaves: these are the highest species of the vegetable series. Of the third which remains in the whole of terrestrial vegetation, about a half consists of monocotyledons, that is to say, of plants which have also apparent flowers, but which spring up with a single seed-leaf; such are palms, grasses, reeds, and sedges. Finally, the last sixth comprehends the acotyledons or cryptogams, that is to say, plants with flowers concealed or non-existent; fungi, mushrooms, mosses, algæ, and other families of plants which germinate without any primordial leaf, and which, in consequence of their rudimentary organization, occupy the lowest place among living beings. However, the proportions between the three great classes of vegetable species vary in the different countries of the world. The great general law recognized by Humboldt, and brought fully to light by M. Alphonse de Candolle, is that the proportion of dicotyledons increases gradually from the poles to the equator, while the monocotyledons and the cryptogams become relatively more numerous on nearing the poles. Thus warmth of climate is favourable to the dicotyledons, but cold moisture is harmful to them, and in all countries where rain is very abundant the proportional number of the monocotyledons is increased.*

A question still more important to man is to know what relative extents are occupied on the surface by absolutely barren spaces, herbaceous regions, and forests of great trees. Districts entirely destitute of plants are very few; deserts and even changing dunes have their special floras, and even the abrupt walls of rocks are covered in many places with an incrustation of lichens. Thus during the rainy season the Black Rocks of Pungo Audongo, in the country of Angola,

* Alph. de Candolle, *Géographie botanique raisonnée*, vol. ii., p. 476.

appear covered with an immense drapery of velvet, which is nothing else than a network of an infinite number of algæ: when the heat comes, these coatings are dried up and peel off, causing the grey and yellowish lines of the rock to reappear.* We may therefore consider the earth as practically clothed with plants throughout its extent; but it is most important to know the part of its surface which is shaded by trees. This is an estimation which has not yet been made, although it presents the highest interest, from its connection with the study of the variation of climates and the history of humanity. If we assign to all the forests a surface equal to that of a quarter or fifth part of the land, this is only a hazardous approximation. Botanists have confined themselves to tracing on the north of the

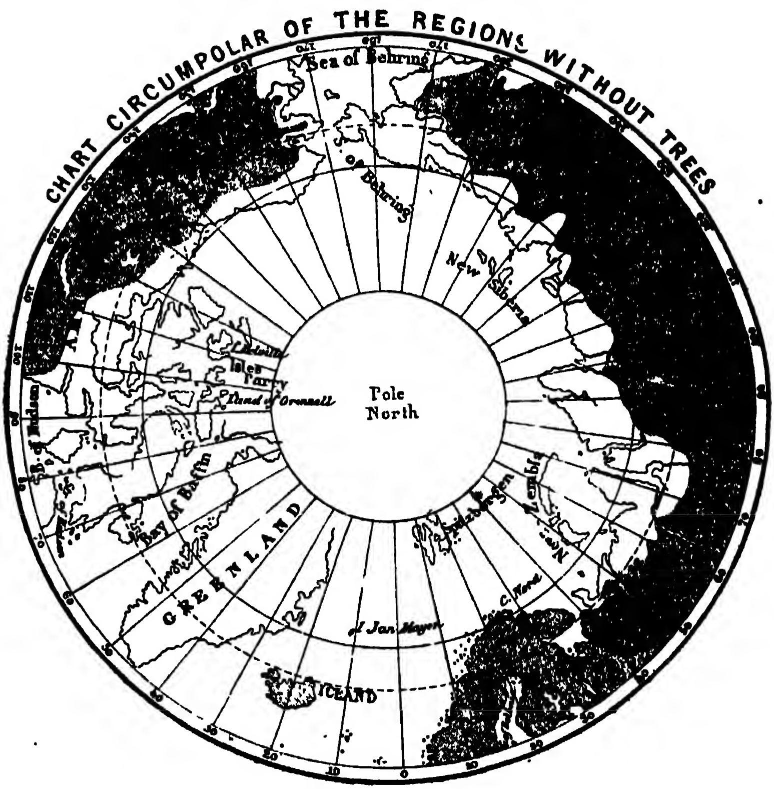


Fig. 163.—Map showing treeless regions around the North Pole.

* Friedrich Welwitsch, *Ausland*, No. 16, 1868.

continents the limits which polar cold fixes for trees. This limit is found in Scandinavia between the 70th and 71st degree of latitude, which is not passed by the birch-trees; in Siberia the larches, which are the hardiest trees of the country, advance as far as the 68th degree; in North America the firs grow on the banks of the Coppermine River up to the latitudes of 68 and 69 degrees, and in Labrador up to that of 58 degrees To the south of this frontier of arborescent species no country is absolutely deprived of trees, and even the southern extremities of the continent which advance in the direction of the Antarctic pole have extensive forests

Certain wooded surfaces of uninhabited countries have no less than several hundred thousand square miles in a single stretch. Formerly, too, the greater part of the regions inhabited by civilized men bore vast forests, which the axe and fire have since greatly thinned. Gaul was covered with trees from the Ocean to the Mediterranean, and

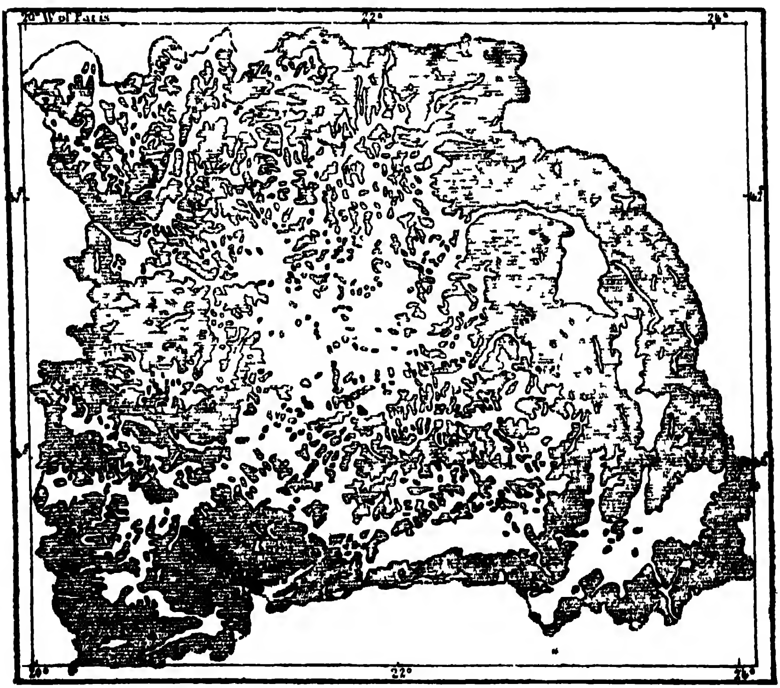


Fig 164 —Forests of Transylvania.

the cultivated lands were simply clearings like those of the American pioneers in the solitudes of Michigan. The Vosges, a chain of French

FORESTS OF THE VOSGES

Engraved by A. Vuillemin.

Drawn by Erhard

mountains which is still wooded along the greater part of its extent, was a "Black Forest" like the corresponding system which rises on the other side of the valley of the Rhine. In Germany the great Hercynian forest had, according to the testimony of Roman writers, a length of sixty days' march, and now there remain only fragments scattered over the sides of the mountains. Scandinavia, Transylvania, Poland, and Russia still present very vast wooded tracts, estimated in some districts at nine-tenths of the surface, the towns and villages occupying mere "clearings." But there too the work of clearing is accomplished with great rapidity. History and personal examination teach us also that in consequence of the diversity of the combined influences of heat and moisture, the contrast between the Steppes of grass and the great forests was formerly as great as it is now in Louisiana between the savannahs and "cypress groves," and in the plains of the Amazonas between the *llanos* and *selvas*. The vast sea of grass succeeded without transition to the immense forests; the flowery surface of the "Tchornosjoin"* extended over half Russia, while the other half was a boundless forest intersected only by lakes and rivers. Now-a-day's the labour of the agriculturist consists especially in mixing the species of plants, and alternating, often in an ungraceful manner, woods, fields, and meadows.†

* See in "*The Earth*" the section entitled, *Plains*.

† See below the section entitled, *The Work of Man*.

CHAPTER II.

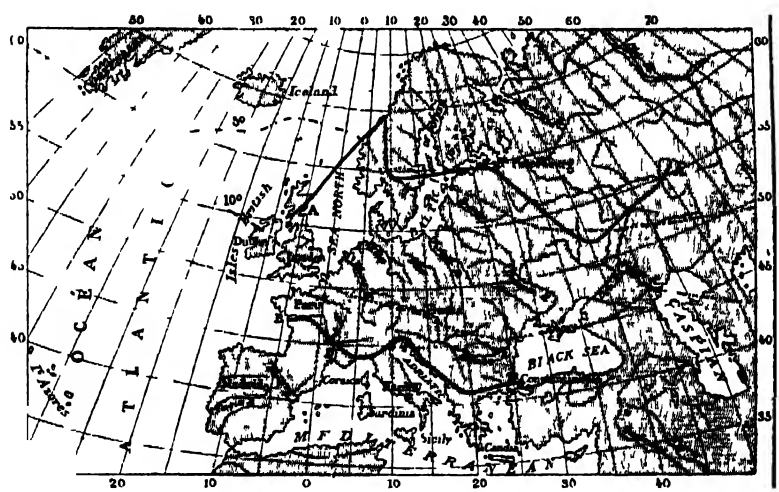
INFLUENCE OF TEMPERATURE, MOISTURE, AND SOLAR RAYS ON VEGETATION.—DISTRIBUTION OF PLANTS.

Each plant has its special domain determined not only by the nature of the soil, but also by the various conditions of climate, temperature, light, moisture, the direction and force of winds, and of oceanic currents. During the course of ages the extent of this domain changes incessantly, according to the modifications which are produced in the world of air, and the limits of the region inhabited by the various species are dovetailed into one another in the most complicated manner. The flora indicates the climate; but what is the climate itself in the apparently confused mixture of phenomena which compose it? The preponderating influence is naturally that of temperature, nevertheless we must not think, as most botanists did till very recently, that the limits of the zone of vegetation of each plant are marked on the continents by the sinuosities of the isothermal lines. In fact, as Charles Martins* and Alphonse de Candolle† remark, each plant requires for its germination and development a certain amount of temperature, differing according to the species. With some, life resumes its activity after the sleep of winter, when the thermometer marks three or five degrees above the freezing-point; others need a heat of 18, 20, or even 25 and 35 degrees before taking the first step in their career of the year. Each species has, so to say, its particular thermometer, the zero of which corresponds to the degree of temperature when the vegetating force awakens its germs. It is therefore impossible to indicate by general climatal lines the limits of habitation for such or such species, since each one of them has for the commencement of its vital period a different starting-point.

In order to know the heat necessary for plants it would be needful, not to seek for the average result of the alternations of heat and cold during the various seasons, but to estimate the number of hours

* *Voyage en Scandinavie*, p. 89. † *Géographie botanique raisonnée*, p. 36.

during which the temperature is maintained above the degree which is for each plant the initial point of its development. It is true that in this estimation the relative number of hours of the day and night are not taken into account, each of which must certainly influence vegetation in a different manner; but such as it is, this calculation is still the truest that it is possible to establish, especially for the annual species which exist only in germs during the winter, and which have not, like trees and perennials, to protect their trunks and branches against the severity of the cold. Thus the climates of London and Odessa, which resemble one another so little in their summers, winters, and extremes of temperature, are nevertheless the same for vegetable species, whose development commences at 7 or 9 degrees above zero, and which require the same sum-total of heat to arrive at maturity. Even climates so distinct as those of Edinburgh and Moscow, Stockholm and Konigsberg, London and Geneva, must produce the same effects on plants which, starting at a certain degree of the thermometer, require the same quantity of heat in a longer or

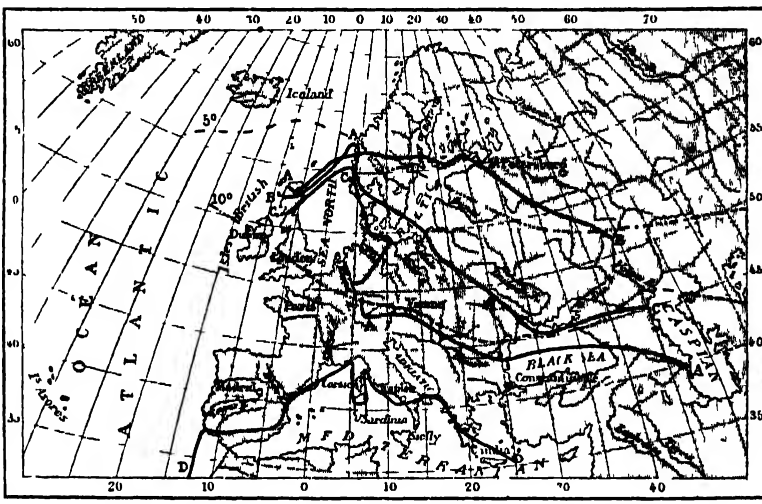


AA *Limits polar of Aquilegia vulgaris* — — *Lines isothermal at 5° & at 10°*
BB " " *of Campanula erinus*

Fig. 165.—Map to show the distribution northwards of *Aquilegia vulgaris* and *Campanula erinus*.

shorter space of time. It results from this, that the areas of habitation of the species have the most various outlines. While on the side of the North Pole the limits of the common columbine (*Aquilegia vulgaris*) and the *Campanula erinus* approach very nearly the course of

the isothermal lines of Europe, the frontiers of other zones of plants traverse the continent in all directions, so that it is as impossible to find the least appearance of parallelism in them as in the lines of equal temperature. We may quote as examples, the curves described by the polar limits of certain well-known trees and shrubs, the holly, the *Chamærops humilis*, the beech, ash, and jasmine. Among the

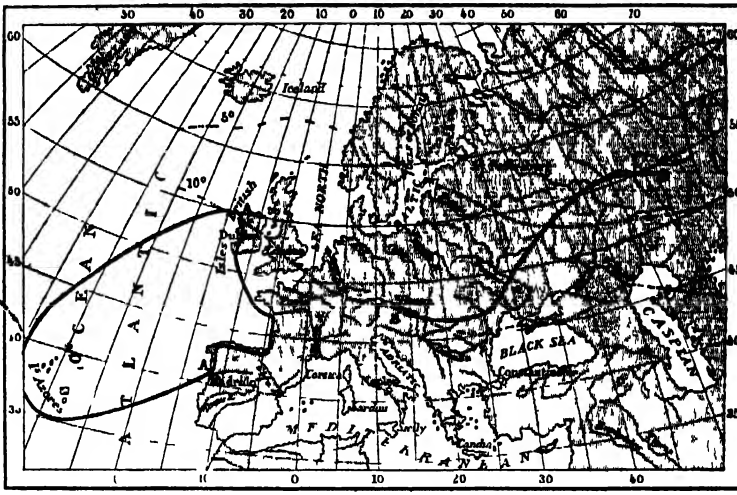


AA Limits polar of holly — DD Limits polar of chamaerops humilis
BB " of the ash — - - Lines isothermal at 5 & at 10°
CC " " of the beech

Fig. 100. Polar limits of the holly, ash, beech, and of *Chamærops humilis*.

plants of Europe there are even some whose limits indicate an absolute antagonism between the climatal conditions which are necessary to them. Thus the *Dabœcia polifolia*, a delicate plant which fears the cold winters and hot summers, only quits the Azores with their moist and equable climate, to venture on the Atlantic coasts of Portugal, Spain, France, and Ireland, where rains are abundant and the cold is tempered. The dwarf almond, on the contrary, spreads itself fearlessly from the banks of the Danube to the foot of the Ural mountains across the Russian steppes, where dry and very cold winters succeed to excessive heat.

According to the method of observing temperatures first indicated by Reaumur and subsequently supported by Boussingault, Gasparin, and particularly by Alphonse de Candolle, we are enabled to explain the sinuosities which the limits of vegetable areas present. This



AA Limits polar of Dabœcia polifolia — — Lines isothermal at 5 & at 10°
BB " " Amygdalus nana

Fig. 167.—Polar limits of *Dabœcia polifolia* and of *Amygdalus nana*.

method, based upon observation, consists in computing the "amount of heat" necessary to the complete development of each plant; that is to say, in calculating daily the degrees of average heat which exceed the temperature at which the plant has commenced its life for the year, and reckoning up the sum-total of these daily heats. Certain plants belonging to the frigid zone, which can germinate and expand their leaves and ripen their fruits in a few days of polar summer, are satisfied with a sum of 90 degrees. Barley, which of all the cereals advances furthest in the direction of the pole, enters its period of growth when the temperature has exceeded at least 9 or 10 degrees, and in order to arrive at maturity, demands a sum of 1,800 degrees, whatever may be the average of the seasons it passes through. According to Seynes, wheat commences vegetation at 12 degrees above zero, and receives about 3,600 degrees till the time of harvest, which varies according to the climates. The maize, a more southerly plant, requires a sum of 4,500 degrees, and its starting-point is at the 55th degree of the thermometer; while the vine demands 4,850 degrees, commencing with the 50th degree of the scale. Finally, Alphonse de Candolle considers that the date-tree needs a total heat of about 9,200 degrees before it can ripen its fruit.* The

* *Géographie botanique raisonnée*, p 396.

greater part of the plants of the temperate zone can support cold of 28°, 29°, or even 36°, without their vital force being destroyed, but none can germinate or grow at temperatures below the freezing-point. In the mountains Saxifrages and Soldanellas flourish even under the snow, but the water which supplies their roots and the air which surrounds their stems have a temperature above freezing-point. The researches of Alphonse de Candolle show that the growth of vegetable species commences on an average at 41 degrees in the regions of western Europe. Still we cannot say that in the starting-point of the growth of each plant we have an absolutely fixed limit, like the degree of temperature at which metals begin to melt; it is probable that, according to their vigour and their various surrounding conditions, certain individuals are quick and others slow to spring forth. Besides, under climates always spring-like, as that of Madeira, plants only commence their annual development after having reposed during a certain period, in order to have time to renew their tissues. Thus the vines of Madeira only begin to vegetate towards the end of March, when the temperature is already 61·4 degrees centigrade; though during all the winter the average heat, which does not descend below 63·5°, would have been more than sufficient to develop the vine and cause its fruit to ripen. In the same way on the plateaux of tropical countries, where a perpetual spring is enjoyed, the plants repose during the winter period; they preserve their leaves, but they do not produce new ones; they develop flowers and fruit, but only those of which the buds have already germinated during the summer.*

The relative dryness or moisture of the various countries is also among the principal causes of the limitation of the areas of species: a too rainy atmosphere drowns the plant; the want of aerial vapours burns it up. Thus many plants do not penetrate into the dried-up Steppes of Russia, where the temperature would otherwise be favourable to them; others cannot be acclimatized to the west of Great Britain, where the annual quantity of rain is enormous. The species which are developed in these moist countries have a charming freshness: the aspect of the trees and meadows shows that they are incessantly watered by rain. In tropical countries, where the annual heat is always sufficient to cause the plants to arrive at maturity, it is the influence of moisture which preponderates. The limits of the zone of rains are also the limits of the zone of vegetation.

* Karsten.

Light, as well as heat, is one of the most important conditions of vegetable life. Alphonse de Candolle has ascertained by direct experiments that of two plants sown on the same day, that which is exposed to the solar rays is contented with a smaller amount of heat to develop and ripen. It is thus to the greater intensity of light that a number of mountain species owe the rapidity of their growth, their brilliancy, and the relatively large size of their flowers. On all the mountain-tops of the south of Europe the Alpine plants, in order to grow and come to maturity, are satisfied with a much less amount of heat than the species inhabiting the plains situated at a great distance to the north.*

Another fact, much less studied, but perhaps not less important than that of heat, contributes to the unequal distribution of plants; this is the chemical power of the solar rays. It would be quite natural to think that this power increased from the temperate to the tropical zone proportionally to the force of the sun; however, judging from several photographers who were not able to obtain their proofs so easily under the dazzling sunlight of South America as in the changeable climate of England, it was till quite recently doubted whether the chemical power of these rays increased in the direction of the equator. At length Mr. Thorpe has removed these doubts by observations made at Para on one of the arms of the river Amazon. The averages of chemical intensity are from 7 to 34 times greater at Para than at the Kew observatory; but while in England this intensity slowly increases and diminishes each day without abrupt transitions, under the tropics it changes in the most sudden manner in the rainy season. When the showers accompanied by electrical discharges fall all at once from the sky, the chemical intensity ceases completely, and then acts again with great force as soon as the storm has spent itself.†

Under temperate climates abrupt variations of chemical light are less frequent than in tropical countries; but nevertheless they are much stronger than the variations of heat. In fact, from the month of December to the month of June differences from 1 to 20 have been ascertained in England and Germany in the activity of the luminous rays. This is because the influence of these rays does not only depend on the position of the sun in the heavens, it increases or diminishes according to the innumerable changes which are effected in the atmospheric ocean. Thus the whitish clouds which

* A. de Candolle, *Géographie botanique raisonnée*, p. 310, and following.

† Roscoe, *Lecture at the Royal Institution.*

veil the sky like light draperies give a greater chemical force to light, and the effects make themselves immediately felt upon nature; but if the clouds thicken, and interpose themselves in black masses between the sun and the earth, then the action of the luminous rays immediately decreases, and a sudden ebb succeeds to the full tide of vital force which was distributed from the sky.*

With the perturbations in climate which produce the incessant alteration of clouds, fogs, and invisible vapours, we must include the changes caused by the myriads of grains of dust and floating germs, and by all the emanations of carbonic acid, hydrogen, and ammonia, which escape from the earth, and disturb the purity of the air. It is thus very difficult, in the present state of science, to indicate approximately, even for the best-known countries of western Europe, the relative value of the chemical action exercised on an average during the year by solar rays. It would be still more difficult to trace on the circumference of the globe isochemical lines analogous to the isothermal lines. This is a conquest of science reserved for future observers. Nevertheless, the researches of Messrs. Bunsen, Roscoe, and other savants, have already proved that the power (*l'actinité*) of the solar rays is subject to greater modifications than the heat; the lines of equal chemical climate must consequently much exceed the lines of equal temperature in their curves and abrupt windings. If there are no chemical winds like moist and warm winds, it is precisely these latter which incessantly modify those changing masses of vapour in the atmosphere which alternately diminish, and increase, the force of the sun's rays.

Thus the extraordinary difference between the floras of two neighbouring countries the temperature of which is visibly the same, may perhaps be explained by the enormous influence which the state of the sky exercises. Thus flowering shrubs do not grow in the Färoe Islands, and we only see brushwood and meagre bushes there, although the temperature is only one degree below that of Carlisle, in England, where we have fine forest vegetation. In fact, if the heat is the same, the light is very different. The sun's rays which penetrate the mists of England are in great part absorbed by the thick fogs of the Färoe Islands, which the ancient navigator Pytheas believed to be a sort of "marine lungs," where air, water, and mud were confusedly mingled. Perhaps, too, it is to a greater chemical and luminous force developed during the long days that we should attribute the singular rapidity with which the plants of the north shake off their winter sleep at the

* Rod. Radau, *Revue des Deux Mondes*, 1st Nov., 1866.

time of the sudden invasion of spring. In a few days all the trees are covered with buds and leaves, while months elapse in more southerly latitudes between the budding forth of the different species. Not only do the plants indigenous to the north, but those also which are acclimatized in these regions, open their buds much sooner than might be expected according to the habits of these plants in southern countries. At St. Petersburg, under the 60th degree of north latitude, it has been ascertained that the budding of the birch-tree, the first signs of spring-tide life, precedes that of the lime-tree by five days, and the flowering of the common *Alchemilla* by only 18 days, while at Breslau, situated 8 degrees further to the south, the intervals are respectively 15 and 51 days.* "The further we advance to the north," says Alphonse de Candolle, "the more does light replace warmth in utility."

Thus we see the questions relating to the natural areas of plants are most complicated, and that it is not without very long and patient study that botanists are able to determine precisely what are the natural history and distribution of each plant, and what are the manifold causes which arrest its extension beyond certain limits. Not only must we take into account the alterations of temperature, light, and of the chemical power of the solar rays, but it is necessary also to estimate the effect of all meteoric phenomena, to appreciate the influence of dryness and moisture, of long rains and passing showers, of exposure, of different altitudes and of inequalities of the ground. Besides all these conditions of the climatal circumstances, it is necessary also to know what is the vitality belonging to the plant itself, what its power of distribution over the earth, and the strength of its resistance to the destructive agents which surround it. It is also important to know the former distribution of continents and seas in geological times, so as to learn what obstacles, such as arms of the sea or chains of mountains, may have arrested the distribution of certain plants over more extended areas. Each plant has its separate history, its peculiar characters and geographical distribution, and thus it is to the extreme diversity of the conditions of existence that we owe the wonderful variety which is presented by the grouping of species on the surface of the globe.

* Auton von Etzel, *die Ost see*, p. 239.

CHAPTER III.

PARTICULAR HABITATS OF SPECIES.—SALT-WATER AND FRESH-WATER PLANTS.—LITTORAL SPECIES.—PARASITES.—TERRESTRIAL SPECIES.—INFLUENCE OF THE SOIL ON VEGETATION.—PLANTS ASSOCIATED TOGETHER.—SEA-WEED.—EXTENT OF AREAS.

MOST plants occupy but a small portion of the space circumscribed by the general limits which climate has traced for their habitation. This is because, according to their nature, certain special physical conditions are also necessary to them, without which germination and growth are impossible. Thus, to cite the most striking example, the aquatic vegetation is composed of species quite different from those which grow on dry land. Excepting in the undecided zone alternately covered and laid bare again by the waters, and where plants called amphibious are developed, the two floras are absolutely distinct. If it be true, as certain botanists think, that some kinds of marine algæ produce terrestrial plants of the mushroom tribe, the germinative power would in this case only exercise its force to transform completely the structure and appearance of the plant.

The contrast of the floras is scarcely less absolute between fresh and salt water than between the seas and the continents. The Ocean has its special plants, some floating freely over the waves like the *sargasso*, or "grapes of the tropics," others clinging to the rocks and ledges of the shore. The rivers, lakes, and ponds of fresh water have also their particular species, potamogetons, swaying like long hair at the will of the current, water-lilies spreading their broad leaves of an emerald green over the transparent water, innumerable confervæ, forming a continuous layer of vegetable matter on the surface of the pond, resembling from afar the surface of a meadow. The plants which flourish equally in fresh and in salt water are very few, and usually are only met with in the estuaries of rivers where the tide ascends, and where the mingling of the waters takes place. As to the turbaries, they are entirely composed of a particular set of plants which press against each other, and contain water in their

interstices as in an immense sponge.* The vegetation of the shores themselves presents one of the most striking contrasts according as they surround fresh waters or seas saturated with saline substances. Thus the deposits of the Ocean, the sand or clay of which is strongly charged with sea-salt, produce in abundance sassify, samphire, thrift, and other plants generally of a somewhat dull appearance, which give a special physiognomy to the shores. In the interior of continents a similar flora is only found around salt lakes and in districts where springs of salt water rise from the earth; it is indeed the sight of these plants which has often urged miners to pierce the soil so as to discover there banks of rock-salt hidden in the depths of the ground. Other kinds of plants seem to require not the sea-salt, but the vapours which escape from it. Such is the case with one of the most charming heaths, *Erica sylvatica,* which grows in the low plains around the Gulf of Finland, the Baltic Sea, the North Sea, the Channel, the Bay of Biscay, and which is found also on the coasts of Spain and Portugal, without ever having been met with at more than 150 miles from the shore.

The atmosphere possesses its special vegetation as well as the waters. Certain plants demand from the earth simply a support, and draw from the air all the nourishment they require. Multitudes of other species never grow on the bare earth, but fix themselves on the hidden roots, stems, or branches of other plants which serve as a nourishing soil to them. Lianas of all sorts, orchids, passion-flowers, bignonias, euphorbias, apocyneas, ferns, mosses and lichens, group themselves thus into aerial forests, and, mixing with the foliage of the trees which bear them, adorn them variously with garlands, bouquets, tufts of verdure or flowers. Upon these parasites other parasites live, and in certain tropical forests, where each tree is a whole world of plants, the foliage of the interlacing vegetations presents such a confusion of forms that the eye of a most experienced botanist alone is capable of distinguishing them.

Finally, even the interior of the soil has its particular flora, composed of truffles and other cryptogams, which only receive the influence of the atmosphere through the fissures of the earth. Grottoes, too, to the very end of their labyrinths, have plants which shun the light, and in the forests certain species of vegetables, almost always white or pale-coloured, hide themselves in the shadow, at the foot of the great trees, and raise their delicate stems above the carpet of moss and dry leaves.

* See in *The Earth* the section entitled, *Lakes and Marshes.*

Among the much more numerous plants which bury their roots in the ground, and wave their leaves in the open air, there are some which prefer a sandy soil; others grow best in a limestone country, others again on gravel, stiff clay, or in the fissures of granite. Some botanists have even attempted to class plants according to the chemical composition of the soil they affect. It is certain that many kinds, even without counting those which grow on salt lands, are met with exclusively on their favourite soil. The chesnut, the purple foxglove, and the common broom delight in a siliceous soil; the *Carex arenaria*, and other ordinary plants of dunes, and, under tropical climates, the cinnamon-tree, require almost pure sand; limestones have also their species, which do not thrive elsewhere. Nevertheless, it does not seem to be so much on account of the substances which they contain, but rather because of their physical properties, such as hardness, density, and porosity, that these different soils nourish particular species of plants. If the composition of the rock remain the same, but become at the same time more disintegrated, allowing the outer air and moisture to penetrate more readily, the vegetation will instantly change, and we shall see species appear on the chalk or clay that we might only expect to find on sand. Thus when the botanist leaves a country where, in consequence of the resemblance of the physical conditions of the soil, the same rocks are always covered with the same vegetable carpet, he perceives with astonishment that species forsake the soil, which he believed to be necessary to them. Of 43 plants, which Wahlenberg had only observed on the chalk in the Carpathian mountains, he found 22 on the crystalline rocks of Switzerland and Lapland. Similarly, of 67 species, which in Switzerland exclusively grow on calcareous ground, 36 are found in the surrounding countries on soils, the chemical composition of which is quite different, and one might believe that further researches would result in reducing still more the number of plants, which are absolutely peculiar to one kind of soil.* Besides, as M. Theodore de Saussure has proved, the tissue of many plants seizes hold indifferently of the most abundant and most soluble substance which is found round the roots: the ashes of the Norwegian fir are not of the same composition as those of the fir-tree of the Jura.

Not only do species of plants know how to choose the soil that best aids their growth, but they also seem to exercise a kind of discrimination in their associations with other plants, either it is that they demand exactly the same physical conditions of soil, or else that they

* Alph. de Candolle, Ch. Martins.

SARGASSO SEA

Arranged by A. Vuillemin after Mr. Lap...

...y Erhard

...MAN & HALL LONDON

seek a shelter. Without speaking of the parasites which have no independent life, a number of "social" species are always near together, and by the harmony of their grouping impart some sweetness and friendliness to nature. Thus the approach to a forest is announced to the traveller by little plants and shrubs which do not grow in the open country; the gay colours of blue corn-flowers and poppies are always mingled, at least in western Europe, with the light ears of corn; herbs that agriculturists qualify as "weeds" associate themselves invariably with the crops in our fields; plantains and potentillas grow together on the road-side and, so to say, under the very feet of men; the châlets of the Alps and Pyrenees are surrounded with nettles and docks which rise in tufts above the short grass of the pastures. Finally, the grassy steppes, American prairies, savannahs, or pampas are nothing else than immense colonies of social plants. By contrast, the deserts with their burning soil often present over vast areas only the meagre verdure of a single species of plant. Thus the clay of the plateau of Utah only allows the roots of an *Artemisia* to penetrate into its fissures, and over a great part of their surface the deserts of New Mexico and Arizona have as their sole vegetation only the gloomy and fantastic candelabra of the giant-taper.*

The Ocean, like the earth, has its monotonous tracts of plants; there are whole fields of sargasso (*Fucus natans*), which are found in the centre of several maritime basins, and notably in the immense triangular space comprised between the Antilles, the Gulf-stream, the group of the Azores, and the archipelago of Cape Verde. Columbus crossed these parts filled with marine plants, and for his companions it was not the least among their terrors to see these long runners which retarded the progress of the ship, and made the unfathomable sea appear like an immense marsh. Interlaced in floating islands and islets which follow each other in interminable processions these plants change the surface of the ocean in certain places to a kind of meadow of a greenish-yellow or rust-colour, the waves raise these masses in long undulations and surround them with borders of foam; fish sport by hundreds under this vegetation which shelters them from the sun; myriads of little animals, crabs, shrimps, serpulæ and shells run, climb, and incrust themselves on the interlacing stems of these migratory forests, and traverse with them the extent of the seas.

It was formerly believed that this floating weed of the Atlantic had been detached by the breakers from the shores of the Antilles and Florida, and then carried hundreds of leagues from land by the Gulf-

* See in *The Earth* the section entitled, *Plains*.

stream; all these masses borne along the course of the waters would be at last united as in the centre of an eddy in the space surrounded by the waters of the great circular tourbillon of the North Atlantic. This notion was not correct, the fuci of the Ocean originate and are developed on the surface of the waters. Neither roots nor the least indications of bulbs can ever be discovered in them which could have clung to the earth and which the waves might have torn away. Each stem is abruptly terminated at its lower extremity by a kind of cicatrice, and is evidently only a detached branch of another plant; vesicles full of air, which have given this fucus the name of the "tropical grape," serve as floats to sustain it on the water, while hundreds of foliaceous membranes rise vertically above every islet of the weed, so as to absorb the quantity of air which these organisms require in order to grow and propagate themselves.

It is true that all these meadows of seaweed circulate under the influence of the winds in the eddy formed by the Gulf-stream and the equatorial current; but instead of having been brought by these marine rivers, they are, on the contrary, arrested by them, and accumulate in rows along their inner shores. Only a small number of plants penetrate into the sea of the Antilles and Gulf of Mexico by channels between the islands. The sea of weed properly so called of the North Atlantic is comprised between the 16th and 38th degree of north latitude, and extends from east to west, from the 45th to the 75th degree of longitude. In this immense space the weed constitutes two separate masses, as if a branch of the equatorial current bent towards the north, and thrust back to the right and left the meadows of sea-weed. We can venture to estimate the surface of this sea of weed at more than four thousand square miles; in the other oceans, the North and South Pacific, and South Atlantic, it covers enormous surfaces. If ever the agriculturists of Europe and America put into execution the idea of M. Leps, who proposes to load ships with this weed, they would be able to provide themselves amply with this manure for the improvement of their crops.*

It appears, from the numerous comparative studies of Alphonse de Candolle, that the general form of the area occupied by each plant is that of an ellipse a little elongated from east to west under the temperate, and from north to south under the tropical, latitudes. This natural arrangement is easily understood, for in the various zones the greatest diameter of the ellipse ought to indicate the direction in

* Leps, *Annales hydrographiques*, 1857, fourth term; *Bulletin de la Société de Géographie*, Sept. 1866, Laverrière.

which the climate presents most equality over a more considerable extent. It is a remarkable fact that the area occupied by the species is the more extensive the simpler their organization is, and that they likewise seem to possess a greater antiquity. Thus the cryptogams, which are the least developed plants, occupy the largest surface. In the same way marine species have an average area more extensive than that of the terrestrial species; herbaceous plants occupy a more considerable area than trees; and finally, the annual phanerogams have a country of larger dimensions than the perennial and woody phanerogams. "The area of plants is in inverse proportion to the complication of their structure." It is also very remarkable that from logical causes, probably anterior to the present state of the globe, the average area of species diminishes gradually from the Arctic Pole in a southerly direction.

No kind of flowering plant, not even the nettle and purslane, the most faithful of the companions of man, inhabit the entire earth. Only eighteen species are reckoned which show themselves at the same time on half the terrestrial surface, and the total number of known plants, which each occupy a third of the globe, is only estimated at a hundred and seventeen. On the other hand, there are plants which botanists have never discovered except in a single ravine or on an isolated promontory. The many islands scattered in the Ocean, St. Helena, Tristan d'Acunha, Juan Fernandez, Madeira, and the Galapagos possess the greater part of these solitary plants, not to be found elsewhere. But there are also parts of the continent where the species have their whole domain, a district of a few leagues or acres, which may be regarded as a sort of continental island. As to the general superficial extent of the areas, it would be, according to Alphonse de Candolle, about the hundred and fiftieth part of the earth's surface, that is to say, nearly 180,000 square miles.

CHAPTER IV.

CONTRAST OF THE FLORAS IN THE DIFFERENT PARTS OF THE WORLD.—INSULAR AND CONTINENTAL FLORAS.—INCREASING RICHNESS OF VEGETATION IN THE DIRECTION FROM THE POLES TO THE EQUATOR.

CONSIDERED as a whole the continents themselves, like the more restricted areas, present remarkable contrasts between their floras. Thus taking their disproportions as to extent into account, the New World appears to be much richer in species than the Old. This fact is explained by the general disposition of the two Americas, and its chains of mountains almost all running in the direction from north to south. In consequence of the position of the Andes and the Cordilleras, the mountains of Brazil, the Alleghanies, the Rocky Mountains, the Sierra Nevada, and the Coast Range of California, it is found that under each latitude the most various climates succeed each other on the opposite slopes, and in consequence different species are developed in each of these distinct climates. In the Old World it is not thus, for most of the mountain-chains, the Pyrenees, the Alps, the Balkans, the Caucasus, Mont Taurus, the Himalayas, the Karakorum, the Kuenlun, stretch in a direction from west to east, and consequently the climates and floras are not modified in the same direction, but by very gradual transitions. On the other hand, Africa, notwithstanding the situation of the greatest part of its mass under the torrid zone, is relatively less rich than the other continents in species of plants. This is explained by the general uniformity of the country, the few high chains of mountains, and the very slight moisture of its winds. But the southern extremity of Africa, the English colony of the Cape, is exceedingly rich in plants.

Another contrast has been pointed out by several botanists, that of the relative poverty of the insular, compared to the continental floras. But this question is disputed, and the want of sufficient observations does not allow us yet to decide it. Nevertheless, it is certain that the large islands, such as Great Britain, Sicily, Cuba, and Ceylon, have types of vegetation entirely analogous to those of the neighbouring continents; and similarly the Färoe islands and Spitzbergen have as

many species in proportion as the larger countries lying at an equal distance from the pole. The archipelago of Cape Verde, the Canaries, Madeira, and the Azores have, on the contrary, from three to five hundred species less than are found on the same continental extent. Mauritius and Reunion have also a relatively small number of indigenous plants; and it is quite natural to think, with M. de Candolle, that the poverty of these islands proceeds in great part from their long isolation in the open sea.

The principal fact in the distribution of plants over the surface of the globe is the increasing richness of the floras in the direction from the poles to the equator. Thus the island of Spitzbergen, the best explored of the countries of the frigid zone, has only 90 species, while on an equal surface Silesia has 1300, Switzerland 2400, and Sicily, much less in extent, possesses 2650.* It is true that in many countries of the tropical zone exceptions have been ascertained to this law of the augmentation of species towards the equator, but all these exceptions may be easily explained by soil and local climates. The Sahara has certainly a flora much less rich in proportion than that of southern Europe; but then what a difference there is between these two regions in regard to the physical configuration of the surface! If Egypt has only a thousand plants, while Great Britain, situated much more to the north, presents on an equal extent 1480, it is because the valley of the Nile is only a narrow alluvial land, bounded on one side by sand and on the other by rocks destitute of moisture. Without being deceived by the relative poverty of the Egyptian vegetation, even the Greeks asserted that the number of plants increased more and more towards the south; they even added this fanciful detail, that in the burning countries of the south the ground sank under the enormous weight of the trees that it supported.†

Unger has proposed to divide the surface of the earth into different zones of vegetation, succeeding each other symmetrically from the two poles to the equator. The northern polar zone, to which a still unknown southern pole corresponds, comprehends the icy archipelago of America, Greenland, Spitzbergen, and northern Siberia. Forests are entirely wanting there; thus, as Linnæus says, the lichens, "the lowest of the vegetables, cover the last land." To the south of this extends the Arctic zone, where the first trees and the first crops show themselves. Next comes the sub-arctic zone of

* Alph. de Candolle, *Géographie botanique raisonnée*, p. 1287.

† Carl Ritter, *Geschichte der Erdkunde*.

British North America, Iceland, and northern Russia, characterized by peat-bogs, toundras, and forests of pines, fir, larch, and birch trees. The cold temperate zone, the southern limit of which is found near the 45th degree of latitude, also presents regions of peat-moss and forests, but it is also the especial country for meadows, and its woods are composed of the most varied species. In the warm temperate zone the meadows become rarer, while the arborescent species gain still more in splendour and brilliancy. The palm trees and bananas make their appearance in the sub-tropical zone; but it is in the tropics and at the equator that vegetation is developed in all its marvellous richness. To the south of the equinoctial line the floras succeed each other in inverse order to the Antarctic pole. But, as we can understand, these divisions are for the most part arbitrary, and in nature the transitions are effected from zone to zone in a generally imperceptible manner. It is a remarkable fact that one of the most clearly-defined zones is exactly cut in two by a vast maritime basin. This is the vegetable zone which surrounds the Medi-

Fig 168 —The Mediterranean flora.

terranean from the Gulf of Lyons to the delta of the Nile. The Mediterranean flora is thus a narrow circular band developed over a linear extent of more than 5000 miles.

Owing to the diversities of the earth's surface, the differences

of temperature and climate, owing also to those secular displacements of continents which result in an equal displacing of floras, all countries are distinguished one from the other by a characteristic vegetation. Scandinavia has its forests of coniferous trees, England has its oaks and its meadows, the north of Germany has its lime-trees, Russia its birch-trees, France its elms and beeches. We cannot think of even the Vosges or the Black Forest without recollecting those long slopes covered with firs; and when we dream of the Alps, we always see them in our memory with their clumps of walnut or chesnut trees, their forests of larches, their rhododendrons and their gentians. In the same way we cannot imagine the beautiful country of Italy without olive-trees, cypresses, and maritime pines. The terrible monotony of the Sahara is relieved by fresh oases of date-trees, and towards the southern extremity of the continent, at the Cape of Good Hope, the harsh contours of the hills and mountains are enlivened by their carpet of heaths and many-coloured flowers. The United States have their trees with marvellous autumn tints, where all shades are found at the same time, from the most dazzling purple to the darkest green. The contrast is great between those forests with varied colours and the uniform extent of the prairies on the west, or the deserts of New Mexico scattered over with Cactuses. In South America the forests of Araucarias of the mountains of Chili and the Brazilian plateau, do not present a less striking contrast with the pampas and their vegetation, so rich in leguminous plants. At the other extremity of the world the Australian flora contrasts with that of the whole world by the antique appearance of its eucalyptus and its *Casuarinaceæ*, dating, perhaps, from the Jurassic epoch. The species of New Zealand are distinguished also by their general facies from that of all the continents. Nowhere else do we see so great a proportion of trees and shrubs compared with annual plants; nowhere do the Cryptogams present such a variety of forms. Meadows are wanting, but the ferns grow in immense forests, as at the epoch of the Coal formation. The succession of terrestrial ages which the geologists seek in the fossiliferous strata, and which they estimate at millions of centuries, the botanists may see in summary at the present epoch by traversing the surface of the globe. The floras of the past periods, stored in the strata of western Europe as in an immense charnel-house, still live, more or less modified, in various parts of the globe.

Virgin forests, where man has scarce ever penetrated, save to make a few paths, are among the grandest spectacles of nature. Those of

cold countries, composed for the most part of Coniferæ with straight trunks and dark foliage, have something solemn and august in their appearance. The mighty shafts of the trees are planted regularly like the pillars of an immense edifice, and in the distance appear in mysterious avenues. The branches, widely spread and laden with greyish moss and lichens, only allow a diffused light to pass through their boughs, spreading as they do symmetrically under the vault of thick verdure. A few knotted roots here and there peep from the ground, which is covered with fallen leaves and sown with modest plants, some clustering at the foot of the trunks, others grouped in masses in the open spaces. Nothing from without penetrates into this retired world, excepting it be a ray of sunlight darting like an arrow between two boughs, or the sighing of the wind among the branches.

The great tropical forests have quite another character, and strike us especially by their magnificence, the luxuriance of their vegetation, and the variety of their species. It is not so majestic and regular as a forest of firs or larches, it is a chaos of verdure, an accumulation of interlacing foliage, where the eye vainly seeks to distinguish the innumerable vegetable forms. Above the large tufted tree-tops others are perceived, and palm-trees rise united to each other by an inextricable network of Lianas; broken boughs suspended by almost invisible cordage swing in space; the Pandanus spring like rockets of verdure from the confusion of branches and leaves of every variety, which are disposed in plumes, fans, bouquets, and garlands; orchids expand their strange flowers in the air; trees which have fallen from age disappear under the mass of flowers, and the greater part of those still upright are themselves surrounded, as with a new bark, by spiral stems of parasites with elegant foliage. While in the forests of the north all the trees resemble each other and yet grow isolated like the independent citizens of a free people, the innumerable species of the tropical forest, so different from each other in dimension, form, and colour, seem to be mingled in one and the same mass of vegetation; the tree has, so to speak, lost its individuality in the life of the whole. An oak of the temperate zone spreading its boughs with their rugged bark, plunging its roots into the crevices of the soil, and strewing the earth with its withered leaves, always seems to be an independent being even when surrounded by other oaks like it. But the finest trees of a virgin forest of South America are not independent; twisted round each other, knotted in all directions by cordages of creepers, half hid by the

parasites which strangle them and drain their sap, they are lost in the immense mass of vegetation which covers the entire country.

It is from the even surface of the sea or of a great river that one ought to see the tropical forest, especially when it clothes the sides of an elevated hill from the summit to the base. Under this undulating mass we can hardly imagine the soil that supports it; we might think that the entire forest was rooted in the waters and floated like an enormous pyramidal plant, 200 yards high. Where the hill presents a rapid declivity, great masses of branches, creepers, and their flowers stretch from tree-top to tree-top like the sheets of a cataract. It is a Niagara of verdure. A moist atmosphere, laden with the mingled scents of the plants, escapes from the forest and spreads itself afar; in foggy weather travellers have recognized, at 100 miles out at sea, their proximity to the coasts of Columbia by the perfumes diffused abroad.*

Of all these marvellously rich tropical vegetations, the most varied is that of the basin of the Amazons, as indeed the geographical situation of the country is sufficient to show beforehand, for nowhere else can we find rich alluvial soil, abundance of rain, and power of solar rays so admirably united over such a vast extent. Over a space of many thousands of miles from north to south and from east to west, the plains of the Amazons are nothing but a limitless forest, interrupted only by the wide channels of the river and its tributaries, and marshes and lagunes on their banks, and here and there by glades with high grass where a few scattered trees appear. The botanist stands confounded before the immense variety of plants which present themselves to him. While in the river itself he already sees a series of interlacing trunks and branches still garnished with their leaves, which the current carries away like a kind of floating forest. On the marshy soil of the shore reeds are crowded together, which advance in promontories. On the bank, properly so called, the alluvium deposited each year has its particular vegetation, higher, more tufted, and more entangled with creepers, the more ancient the soil is on which it grows. Beyond this first rampart of new trees, which in many places hides the real forest,† the virgin solitude of the great woods commences, where the flora of the Amazons is seen in all its beauty and all its majesty at the same time, owing to the prodigious number of plants that compose it. The most varied types, climbing herbs, and gigantic trunks are mingled together, light

* Kiddle, *Nautical Magazine*, March, 1865.

† Avé-Lallemant, *Reise durch Nord-Brazilien*.

creepers suspended to the branches connect in one network the boughs of the entire forest. This is a wonderful picture, which ought to be contemplated in free wild nature, either on the shores of some lagune, where the enormous leaves and delicate rosy flowers of the *Victoria regia* display themselves, or else on the surface of a tortuous stream, all festooned with garlands of interlacing plants, which float beside the canoe of the travellers. In no country in the world are strength and beauty, grandeur, with at the same time great beauty of detail, combined in so happy a manner; it is the triumph of living nature. The forest is at the same time grand and joyous, and has nothing of the melancholy of the woods of the temperate zone.*

If all the plants of the world are not found in the vast *selvas* of the Amazons, at least all the genera, even those which are completely missing, still have their representatives. Thus the family of *Rosaceæ*, which gives us the charming eglantine of our hedges and the beautiful garden roses, the greater number of our fruit trees, the pear and the apple, the peach, cherry, medlar, almond, and many others, hardly exists under the tropics; but these plants are replaced by another great family, that of the myrtles, which produces the guava, the pitanga, and a great many savoury fruits, whose names are scarcely, if at all, known beyond the tropical regions. Thus each zone has its special family of fruit trees. In the same way the humble cereals of the north, the grains of which serve as the chief food for man, have equivalents in the neighbourhood of the equator in the great family of the palms, of which so great a number of species live on the banks of the Amazon and its affluents. Each of these rivers has its characteristic species of palm-tree, giving a new aspect to its forests and the villages on its banks. Even on the principal river the varieties succeed each other several times, from the embouchure to the confluence of the Solimões with the Rio Negro, and higher up as far as the mountains of Peru.† The species of this tree, which support the natives with their fruit and furnish them at the same time with refreshing water, with tissue, and with building materials, are still more numerous than the cereals of the northern countries. And yet the Amazonian regions are scarcely known even now save in the immediate neighbourhood of the river-banks, and each new exploration of botanists there will reveal the existence of new vegetable treasures.

* Agassiz, *Conversaçoes scientificas sobre o Amazonas.*

† Id., Ibid.

CHAPTER V.

DISTRIBUTION OF VEGETATION ON THE SLOPES OF MOUNTAINS.—MINGLING OF THE DIFFERENT FLORAS.—UPPER LIMITS OF THE PLANTS IN VARIOUS PARTS OF THE WORLD.—IRREGULARITIES IN THE VERTICAL DISTRIBUTION OF PLANTS.

In consequence of the gradual decrease of temperature on the sides of mountains, zones of vegetation, analogous to those which succeed each other from the equator to the pole over the surface of the globe, are situated one above the other from the base to the summit of mountains. By the flora, as by the climate, we might think we were proceeding in the direction of the polar regions, in proportion as we ascend the sides of a peak at a higher altitude above the plains; but the intervals of climate that it would take days to cross in travelling towards the pole, are traversed in a few minutes of ascent, since in the mountains a height from 175 to 260 yards corresponds on an average to one degree of latitude. At the foot of the plateau, which bears the Cayambe in the equatorial Andes, the vegetation is that of the torrid zone; at the snowy summit of this volcano, which is intersected by the very line of the equator, we find plants recalling those of Greenland; but to whatever height we ascend, we always find living organisms. Above the snow itself the cellules of the *Protococcus* are grouped and live, as in the deepest seas, the sounding-lead still discovers diatoms in infinite myriads.

The limit which separates the flora of the mountain from that of the lower plains is not always very distinct, and we must often traverse vast debateable regions before knowing by the aspect of the surrounding plants what zone of vegetation we have under our eyes. In the same way it is very difficult to distinguish, on the slope of a mountain-chain, the various floras, one above the other, because certain plants are common to two zones at once, and some, from various physical causes and changes, descend below or mount above the normal region of their abode. It is thus that on the sides of the volcano of Chiriqui Moritz Wagner found meadows and green oaks beside euterpe-palms and bignonias.* In the same way, too, in

* *Mittheilungen von Petermann*, xi. 1862.

the Columbian state of Santander, the banana and the sugar-cane flourish excellently at the height of 9,000 feet, in the midst of the region of oaks and birches. There is, therefore, not only superposition, but also an intermingling of climates and forests. In the Cordillera of Valdivia this mixture of floras is such, that trees of the plain mount almost to the lower limit of perpetual snow, owing to the extreme abundance of rain, and to the equality of the climate.*

The mountains where the limits between the zones are more clearly defined are, as we can understand, those whose slopes are cut in abrupt escarpments. A precipitous rock some hundred yards high is most frequently a visible frontier between two floras; one may see a magnificent example of this at the fall of Tequendama in Columbia, where the water plunges from the zone of apple-trees and rye, to fall into that of the palms of the Mauritius. Similarly, a sudden change in the physical conditions of the place can define clearly two zones of vegetation. In Vallouise, not far from the foot of the Grand Pelvoux, we observe, on the southern slope of the mountain of Echanda, a line of demarcation, straight as if drawn by a cord, between the zone of shrubs and that of the short grass of the pasturages; this is because the lower part of the Echanda is sheltered by a promontory, above which the cold wind descending from the glaciers passes freely. On the sides of the volcano of Riñihue, in Chili, M. Frick has remarked also that the line indicating the limit of the trees is perfectly horizontal.†

The phenomena which contribute each in its way to render undecided the limits of the superposed floras vary in their action according to the innumerable diversities which the slopes present. Every difference in the slope, the exposure, the nature, or the hardness of the soil, produces a corresponding difference in the width of the zone, where the plant is freely developed. In one valley well sheltered from the cold winds, open to the warm breeze from the plain, and abundantly watered by rains, the plants of lower countries often ascend to heights several hundreds or even thousands of yards above their native soil; in other places, on the contrary, the plants of the elevated zone favoured by the cold winds which are ingulfed in the gorges, descend to a great depth below the imaginary limit of their abode. In the same way species which live in the neighbourhood of the snows sometimes advance with erratic blocks on the surface of the glaciers and then are driven with their terminal moraine as far

* Grisebach, *Geographisches Jahrbuch, von Behm*, 1866.

† *Mittheilungen von Petermann*, 1864, ii. p. 52.

as the lower plains: at other times they fall from the top of the mountains with fragments of stone, and in passing at the foot of an escarpment we are suddenly surprised to see a foreign colony growing and thriving in the midst of plants of another climate. Even the avalanches of snow which slowly melt in the meadows beneath the passes from which they have fallen leave traces of particular species as signs of their sojourn there. Two laws act in contrary directions on the sides of mountains, one which tends to cause the lower plants to ascend towards the summits, and the other which tends to make those of the high peaks descend, and in consequence of this incessant conflict the limits of the zones are constantly displaced with the oscillation of the climates.*

Since the time of Humboldt Chimborazo and Popocatepetl have often been taken as types of mountains with superposed stages of vegetation; still these two mountains cannot be cited but as representatives of the temperate regions in which they stand, for they are erected upon plateaux, and in order to find a tropical flora we must go to a great distance from their bases. The Orizaba of Mexico, whose regular cone is so well seen from the sea, and the Sierra Nevada of Sta. Martha, which towers 19,500 feet above the shores of New Grenada, are the most striking examples of this arrangement of climates and floras in stages, for from the base we may vaguely distinguish on the slopes a résumé of the vegetation of the globe, from the cocoa-nut palms which bend over the shore, to the Alpine plants the verdure of which is recognized from a distance by the contrast it forms with the whiteness of the snows. On the sides of the volcano of Chiriqui, a mountain of less height, which also stands on the shores of the sea of the Antilles, M. Moritz Wagner was able precisely to measure the height of the successive stages. That of the palm-trees and the *Musaceæ* rises to about 2,000 feet; the tree-ferns and orchids show themselves from 2,000 to 4,000 feet; above them the rosaceous family grows to 5,000 feet; and higher still, from 5,000 to 10,000 feet extends the region of oaks and birches. In the island of Java, the isolated volcanos which rise above the plains of exuberant tropical vegetation are also admirably situated for enabling one to study on their sides the natural and cultivated floras and the crops in their different stages, from the base to the summit of the mountains.

Isolated mountains which are bathed in an atmosphere where the

* E. Rambert, *Les plantes alpines;* Gustav Mann, *Mittheilungen von Petermann*, i. 1866.

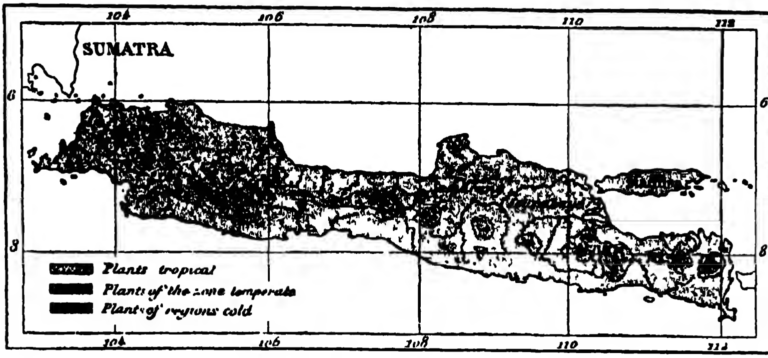


Fig. 169.—Botanical map of Java

meteorological phenomena occur with great regularity, present in consequence a normal series of floras in stages from their summit to their base. Among the mountains which may be considered as types of the regular distribution of the zones of vegetation, we may cite

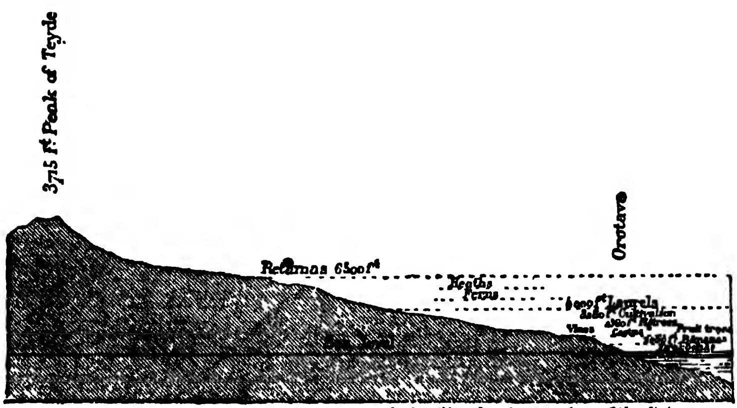


Fig. 170.—Stages of vegetation on the flanks of the Pic de Teyde, Isle of Teneriffe.

the peak of Teyde, the central mountain of the group of the Canaries. On descending the height of this volcano in the direction of Orotava we at first see nothing but *retamas*, always *retamas*, a kind of greyish genista, which delights in a soil of ashes and cinders. All at once a new plant appears, a heath, and soon we are surrounded with heaths on all sides, and the *retamas* have completely disappeared.

One solitary old pine marks the clearly-defined line of demarcation, which separates on the mountain-side the zone of plants of sombre tints from that of verdant plants. In proportion as we descend the heaths are higher and more crowded together, then they are mixed with ferns; towards 3800 feet of altitude the laurels rise here and there in the middle of the thicker brushwood, and the volcanic soil is covered with grass. Below 3300 feet the crops begin, lupins, corn, and a few vegetables, while nettles are seen to grow at the edge of the path. At 2500 feet the first fig-tree is found, and then we enter the region of vines, cactuses, and fruit trees; finally, at 1000 feet we enter the subtropical zone indicated by the bananas and dracænas.*

Among the high mountains of France the Canigou is that which rises most proudly above the plain, and on its sides, which are entirely

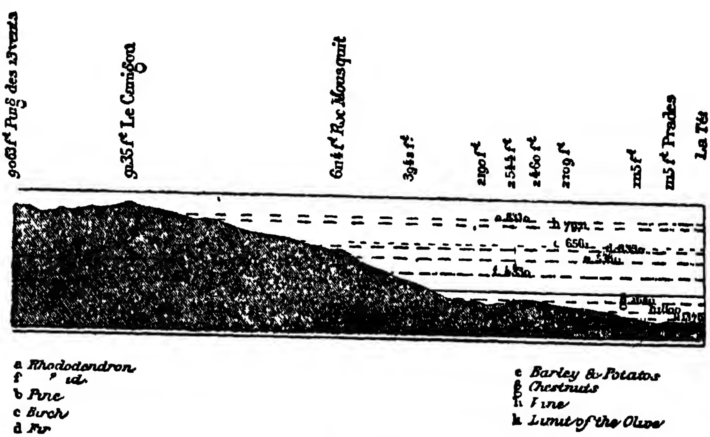


Fig. 171.—Stages of vegetation on the flanks of Canigou.

visible from the open sea, M. Aimé Massot and other botanists have been able to measure with great exactitude the separate zones of vegetation. The olive-trees, which cover the plains of the Têt and Tech, grow also on the offshoots of the mountain at a height of 1300 feet; the vine rises higher, but at 1800 feet it disappears in its turn; above 2500 feet the chesnut ceases to grow. The last fields cultivated are rye and potatoes, which do not pass 3300 feet, a height at which the beech, the pine, the fir, and the birch already suffer from the wind and the cold of winter. The fir stops at 6400 feet, the birch does not venture beyond 6500 feet, but the hardier pine scales the rocks to the altitude of 7000 feet, not far from the summit. Above this the vegeta-

* Piazzi, Smith, *Teneriffe*, p. 266, and following.

tion is only composed of Alpine or polar species. The rhododendron, the first tufts of which showed themselves at 4000 feet, extends to a height of 8000 feet. As to the juniper, it climbs up the mountain, half hiding its branches in the soil to the terminal point 1000 feet high, which is covered with snow during three months of the year.

The stages of vegetation have been studied with care on the slopes of many other mountains of temperate Europe, especially on the sides of the Ventoux, by M. Charles Martins; but it is in the Alps above all that the most celebrated botanists of our century have made their comparative researches on the floras of the various altitudes. The limits of these floras vary, so far as we can understand, according to the form, exposure, and height of the mountains, the nature of the rocks, the moisture of the soil, the abundance of snow, and the meteorological conditions of the surrounding atmosphere. It is, therefore, impossible to give the precise figures on the whole of the Alpine masses, and the averages obtained by savants have only a very general value. Without taking account of the upper limit of cultivation, which varies singularly in the high valleys in proportion to the industry, intelligence, and social condition of the inhabitants, we may say that the vegetation of the plain hardly exceeds 3000 feet; above this height the slopes where man has not violently interfered to change the productions of the soil, are naturally covered with vast forests. Still the great trees gradually diminish in height, in proportion as we rise into a zone where the air is rarer and colder; their wood becomes harder and more knotted, and the hardy kinds, which venture not far from the region of the snows, end by creeping on the ground, as if to seek shelter between the stones. To the north of Switzerland the beech does not exceed the height of 4000 feet, and the spruce fir stops at 6000 feet. In the group of Monte Rosa the same forest growth, which approaches most nearly to the zone of perpetual snow, ascends as far as 6200 feet on the northern slope, while on the opposite side, the larch, still hardier, attains its upper limit at 7200 feet. Higher still, we only see the fantastically-twisted trunks of a few *mugho* pines, rhododendrons, willow-herbs, and juniper-trees, then all vegetation becomes more stunted, and is attached to the ground in order to escape the icy winds, and to allow of its being covered in winter with a protecting layer of snow up to the very edges of the glaciers, and the white surface of the snows, the phanerogamous plants will grow even at 11,500 feet high; we see androsaces, gentians, saxifrages, and the charming thrift with its pink flowers gracefully placed on a cushion of green moss; in the middle

of summer freshly fallen flakes will sometimes half cover these tiny plants, when we might think the snow was veined with blood. Even the highest rocks are covered here and there with lichens resembling rust, and often the very snows themselves are shaded in red, green, or dull-yellow, by a flora of rudimentary cryptogams.

The distribution of the vegetable species is effected in an analogous manner on the sides of other mountain-chains, situated to the north of the Alps, the Vosges, the Erzgebirge, the Sudetes, and the Kjolen mountains; only as we can see on the slopes of Sulitjelma, which rises

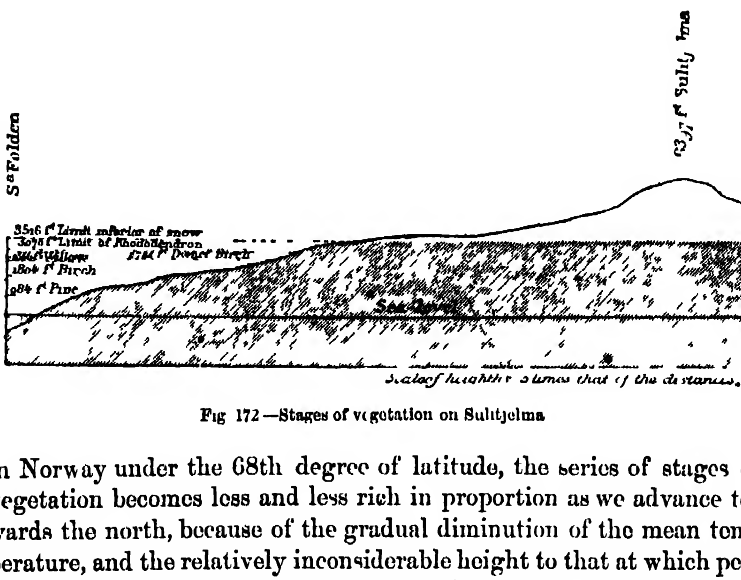


Fig 172—Stages of vegetation on Sulitjelma

in Norway under the 68th degree of latitude, the series of stages of vegetation becomes less and less rich in proportion as we advance towards the north, because of the gradual diminution of the mean temperature, and the relatively inconsiderable height to that at which perpetual snow begins. It is to be remarked, also, that the different species are far from succeeding each other in the same order on the slope of the mountains. The upper limits of plants present the most striking irregularities in this respect, and intersect each other variously instead of remaining parallel to one another, as we might expect at first. Thus the aspen rises to a less height than the beech in the Bavarian Alps, and the contrary occurs on the sides of the Canigou; on the other hand, on this same mountain, the aspen leaves the hazel-nut far behind, while in Bavaria it is distanced by it by about 225 feet. We have attempted to make these remarkable phenomena more intelligible, by means of a diagram.

The polar limits of the various vegetable species do not succeed each other exactly in the same order, any more than the upper limits

of similar plants on the slopes of mountains. These differences in the distribution of corresponding floras are connected with the multitude of causes which hinder the propagation of plants over a more extended area. A plant may be arrested on one side by the cold of winter, on another by fogs, drought, moisture, or the neighbourhood of snows. Each region of the world having its special climate, also

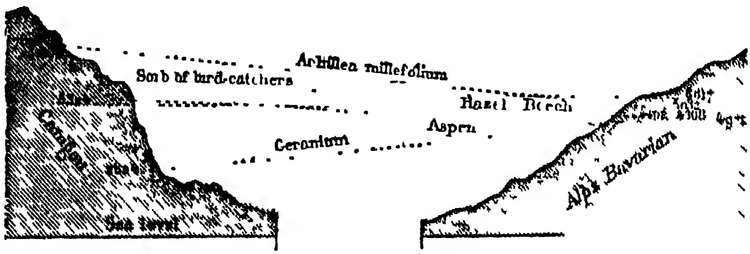


Fig 173 —Comparative height of different species of plants on Canigou and in the Bavarian Alps

presents special conditions for the development of life. Even on the opposite slopes of a single mountain the stages of vegetation present remarkable contrasts. Thus the mountain-pine (*Pinus uncinata*) rises nearly 600 feet higher on the southern slopes of Mount Ventoux than on the opposite side. On the other hand, the evergreen oak mounts to nearly 2000 feet on the northern side, and only to 1800 on the side fully exposed to the midday sun. We observe, too, that each declivity has its special growths, to the south it is the olive-tree, to the north the walnut and firs.* In the Alps of Monte Viso and the Col de Tende it is seldom that we fail to observe a rhythmical alternation between the forests on sides differently exposed: larches cover the escarpments turned towards the south, while firs prefer shady valleys looking towards the north. On the mountains of the tropical zone the contrast is more striking still, since on one side impenetrable forests extend, and the other side has only herbaceous plants for its vegetation. Humboldt observed this contrast on the sides of the Duida, which commands the bifurcation of the Orinoco, and it can also be confirmed on most of the mountains of the Sierra Novada of Santa Martha.

* Charles Martins, *Du Spitzberg au Sahara*, p. 418, and following.

CHAPTER VI.

UNCONNECTED SPECIES.— DISPLACEMENT OF AREAS IN CONSEQUENCE OF GEOLOGICAL CHANGES.—PLANTS OF GREAT BRITAIN.—NATURALIZATION.—INCESSANT MODIFICATION OF FLORAS.

One of the most interesting phenomena of the terrestrial flora is the coexistence of the same plants in two regions separated from each other by vast spaces, where the transport of seeds would not have been possible if nature had not employed other means than those which she employs in the present period. It is certainly difficult in the present state of science to render an exact account of this division of the areas of plants; but one cannot study it too carefully or give too great importance to it, for besides the stratified rocks and fossils, the flowers which spread over the ground recount in their silent language the history of past ages.

Gmelin, and since his time a number of other botanists, ascertained that the vegetation of the mountains of Switzerland does not only resemble the flora of polar regions, by the general physiognomy of its plants, but that it also comprehends species perfectly identical with the plants of Spitzbergen, Greenland, and Arctic America. On the terminal cone of the Faulhorn M. Charles Martins has gathered 132 phanerogams, 40 of which are found again in Lapland, and eight in Spitzbergen. In the same way the "Jardin," which stands isolated in the midst of the glacier of Talèfre, resembles by its scanty flora a polar country much more than a rock among mountains of the temperate zone. In this little ice-girt world, which botanists have lovingly studied to the very furthest corner, 128 species of plants live, but only 87 phanerogams; of this number 50 belong also to the Faulhorn, 24 to Lapland, and five to Spitzbergen. Observations made on other elevated points of the Alps, at the Grands Mulets, and in the pass of St. Theodule, have given analogous results. On the White Mountains of New Hampshire we also find the same species as those of Labrador, many of which belong equally to the mountain flora of the Alps and the Pyrenees. Finally, the Atlas and Abyssinian mountains, the peak of the Cameroons, the volcanoes of Java, the chains

of Brazil and the Andes, and even the rocky escarpments of Terra del Fuego, have among their species some European plants. Enormous distances, from 600 to 6000 miles, separate these divided areas of mountains to the south, and plains to the north, and we cannot believe that birds or atmospheric currents could have carried the species from one region to the other, for the naturalization of species is most difficult in cold countries, and most of these far-scattered plants have neither berries such as the birds seek for, nor winged seeds such as are carried by the wind.

The same difficulties present themselves when it is necessary to explain how a great number of fresh-water species live in rivers and lakes, deprived of all communication with one another. These are plants whose heavy seeds cannot be transported by the air, and which the sea water would destroy in time; nevertheless, these plants have been able to penetrate into almost all lacustrine and fluviatile basins, where the temperature suits them. They are seen in islands as well as in continents; they grow on both sides of wide seas, and in the waters which bathe the opposite flanks of high mountain-chains, and by a remarkable coincidence it is precisely these aquatic species, with necessarily limited requirements, which are found most frequently alike in the different countries of the earth. Respecting these water plants, just as regarding those of the mountains, botanists ask how they have been able to establish themselves at the same time in the cold or temperate regions of the two hemispheres at the opposite extremities of continents, since the torrid zone, which separates the areas of habitation by a distance of several thousands of miles, forms an insurmountable barrier between them. Thus even at the two antipodes, in New Zealand and in the seas of western Europe, Hooker has recognized 25 identical species of algæ. The genus *Spartina* presents the most singular contrasts in this respect. One species, *Spartina stricta,* grows in the United States and in Europe on the shores of the Atlantic, and is found at Cayenne, at Venice, and at the Cape of Good Hope. Another species, the *alterniflora,* found alike on the coasts of America, in the United States, and in Cayenne, only shows itself in France at one spot, the mouths of the Adour, and in England, on the shores of Southampton. Finally, the species called *juncea,* which flourishes in Georgia and in Massachusetts, only appears in the Old World at Fréjus, near the embouchure of the Argens.

It is true that these last-named plants, living always in the sand and alluvial lands of the sea-coast, might easily have been transported

by vessels with the ballast and merchandise from one shore of the Ocean to the other, and have propagated themselves after having remained for a time in sea water. M. Godron has seen the seeds of grasses germinate after immersion during a winter in a salt pool. Darwin and Martins have also proved by direct experiments that certain seeds can preserve their power of germination after having floated on the sea during 28, and even 137, days. They think that a tenth of the plants can thus propagate themselves spontaneously along the shores.* Perhaps even the *Eriocaulon septangulare*, an American fresh-water plant, which flourishes also on the Scotch island of Skye and the Irish district of Connemara, has been carried from Canada by the Gulf-stream. It is known what a marvellous vitality certain seeds possess. Robert Brown caused the seeds of *Nelumbium speciosum*, deposited in an herbarium for 150 years, to germinate. Perhaps, too, the various seeds contained in the Egyptian tombs could, as many botanists assert, have preserved their latent life for thirty and forty centuries. Many geologists, indeed, believe that the rare plants suddenly springing up above the remains of ancient fossiliferous strata originate really from seeds that have been buried during a whole series of terrestrial revolutions.†

However it may be, such phenomena occur in too small a number of plants for us to be able to explain in this way how so many vegetable species having several habitats can flourish at a distance from the sea and all highways of commerce, either in lakes and streams, or on the sides of snowy mountains. We can only imagine two alternatives in the case of these plants,—either their germs have been developed spontaneously on all the spots where the separate colonies are now found, and each mountain summit, each fluvial and lacustrine basin has become an independent centre of vegetable generation; or else the snow-scattered colonies were formerly connected with one another, and have been gradually separated, or even displaced, in consequence of the changes of the surface or climates of the earth. The humble Alpine flowers, hiding in the snows and in the crevices of rocks, would thus relate the great revolutions of the globe.

In fact, during the earlier geological periods the mean temperature underwent frequent changes, as the fossils in the strata of the earth prove. In the same country the climate has been alternately hot, tem-

* *Origin of Species*, p. 365.

† Alph. de Candolle, *Géographie botanique*, p. 1067.

perate, and cold, then it has become heated again, and consequently the living organisms, plants and animals, have been incessantly displaced on the surface of the earth.* Towards the end of the Tertiary epoch, when the regions which have now become the continents of Europe and North America still enjoyed a high temperature, the vegetation must have had a much more southerly character on the whole than in our days: in the same way the scattered lands which surround the Arctic pole had doubtless a uniform flora, composed of plants analogous to those of our temperate zone. But the climate gradually changed, and the cold which was to bring on the glacial period began to reign over the northern hemisphere. There was a repulse of the species which had advanced too far towards the north and missed the necessary warmth. They beat a retreat before the snow and ice like an army in flight. The plants of the polar zone gained little by little on the temperate zone, those of the temperate zone retreated towards the tropics, and by the gradual encroachments of their colonies even crossed the equator and established themselves on the now scorching plateaux and plains of the torrid zone. During the series of centuries of an unknown length which elapsed during the Glacial epoch of our planet, a certain number of displaced species sought vainly to accommodate themselves in their new countries, and ended by succumbing, whilst other plants, favoured by the climatal conditions, grew without difficulty in the land of their exile, or even enjoyed greater prosperity there than in their ancient abodes.

Nevertheless the temperature, changing incessantly like all the phenomena of the universe, entered upon a new phase: to the cold period succeeded an increasing warmth on the surface of the northern hemisphere, and perhaps over the whole earth. The glaciers which filled all the mountain gorges and advanced far into the plains, retreated gradually towards the peaks, leaving in the fields heaps of the earth and débris which they had carried for centuries. To the north the snows of continents and the ice-fields of the sea retreated more and more from the temperate zones, and approached nearer to the poles. Owing to the warmth, plants which the cold had forced to take refuge in the equatorial regions, and had enabled to propagate themselves in both hemispheres, were thus divided into two distinct *corps d'armée*, retiring from each other in proportion as the temperature increased. In the same way the species of the temperate zone gradually encroached on the ground in the direction of the pole, and advancing to the assault of the mountains, took possession of the moraines and ravines abandoned

* See in *The Earth* the section entitled, *The First Ages*.

by the glaciers; but in order to conquer the mountains and polar regions, they were obliged to yield the intermediate plains to other plants which had come from the south. An ever-widening space occupied by a new flora interposed itself between the two separated fragments of the ancient flora, and in our days, after the lapse of ages, the European species of the Glacial epoch have no longer any other country than the Arctic lands and the rocks surrounded by snow on the summits of the Alps and Pyrenees. Like those tribes of mountaineers, Basques, Romanches, and Vaudois, who, to preserve their customs and their nationality, have taken refuge in high valleys, the little vegetable population besieged by the plants of the lower plains have retired to the snowy heights, where they find a climate which reminds them of the Glacial epoch. Thus all distributions of species which cannot be explained by the present condition of the terrestrial surface may be explained by reference to former conditions.

This is not all: to such important alternations of climate are added also, for the modification of vegetable areas, the numerous changes of form and relief to which the continents have been subjected. When Scandinavia was an insulated country, when a vast sea occupied a great part of the plains of northern Germany and Russia, and a strait allowed the Black Sea, the Caspian, and the Gulf of Obi to communicate with each other, there is no doubt that maritime currents and convoys of floating ice served to transport Arctic species to the sides of European mountains. Later, while the countries of Europe rising out of the Scandinavian sea gradually assumed the contours that they have now, their relief was also modified in various ways; the heights were elevated, and thus separated basins formerly united, hills worn away by the waters disappeared little by little, and in their destruction a communication was opened between two valleys formerly distinct; lakes were formed, others were dried up, and rivers changed their courses. Thus the soil with the seeds which former vegetations had deposited there was incessantly altered. Why therefore should we be astonished to see the same aquatic plants flourish in so many basins now completely isolated? Communication which does not exist now existed directly or indirectly during previous geological ages, and that is sufficient to explain the coexistence of scattered areas of habitation. However, in following this path it is so easy to allow oneself to be carried away by daring suppositions that it is important to prove established facts very carefully before adopting them. Thus, M. Schmidt having ascertained that the present flora of the coasts of Siberia and China resembles much more that of the Atlantic shores of

the United States than that of California and Oregon, concludes from it that Asia and America formerly composed a single continental mass, and then that a part of the centre, after having been gradually submerged in the depths of the Pacific, rose again to re-clothe itself with a second flora entirely different from the first.*

The flora of the British Isles is a remarkable example of the changes which have operated during the modern period in the areas of species. With the exception of a single plant of American origin, the *Eriocaulon septangulare*, which is found in a part of the Hebrides,† the whole Anglo-Irish vegetation is of continental origin. The great majority of the species have been propagated directly from France, Holland, and Germany, before the English Channel had been opened by the waves. Another flora in the north of quite an arctic character must have been brought from Scandinavia by icebergs laden with débris; finally, the arbutus, and about ten of the plants growing in the mountainous regions of the south-west of Ireland, are only found again on the shores of the Gulf of Gascony, in Portugal, in Madeira, and the Azores, and there are strong reasons for admitting with Edward Forbes that they formed part of the flora of a great continent, which has now almost wholly disappeared. Thus the modifications of climate and the oscillations of the soil, without counting the still more important changes introduced by the work of man, have resulted in concentrating parts of three very distinct floras in the relatively narrow space of the British Isles. Besides this, 83 species of foreign origin have been naturalized there during modern centuries by the voluntary or involuntary intervention of man, who is himself one of the great geological forces.

Since the discovery of the New World the two continents, which navigation continually joins together, have mutually enriched their floras by the naturalization of new species. At least 35 plants of North America have acclimatized themselves in Europe, and 172 European species have been propagated on the soil of the United States. America has thus greatly gained in this exchange. Europe has discharged on the New World vegetable populations as well as human populations; and these colonizing plants, invaders like the rude pioneers themselves, have in many spots displaced the native species. In less than a century it is said that the common trefoil of Europe has conquered nearly half the continent, from Louisiana to the Rocky Mountains. In Australia, Van Diemen's Land, and New

* *Compte rendu de la Société géographique de Russie*, p. 21, 1864.
† See above, p. 133.

Zealand, the invasion of the conquering plants is accomplished in perhaps a more rapid manner still; a few years sufficed to change the physiognomy of the vegetation in whole districts. The European colonists, occupied only with agriculture and commerce, would willingly leave to their new country the strange flora whose very aspect astonishes them; but from their fields and gardens plants which have come with them from Great Britain escape, and spreading take possession of new domains; more rapid in their triumph than the English themselves, they are incessantly driving before them the aboriginal plants. The ancient flora, scarcely modified since distant geological epochs, is greatly changed in less than a century; one might say that these countries, the last representatives of a vanished period, abandon the fashions of the old times to dress themselves in new costumes. Thus the conquering peoples and the colonists are always accompanied by species of plants, invaders like themselves. The Persians and the Greeks, the Crusaders, the Arabs, the Mongols, and the Russians, have carried the plants of their country with them in their wars of invasion, in the same way as English and American pioneers carry theirs into the solitudes of uncultivated lands. In this point of view the history of the plants which have been naturalized without the knowledge of man is to some extent connected with the history of humanity itself.

If there are botanical areas which increase in extent, there are, on the other hand, many others which are gradually restricted or which even disappear: certain plants have not only been driven back like the Maoris of New Zealand or the Red-skins of North America, they have been completely destroyed, and no longer exist, except in herbariums, or else in the state of dormant seeds in the crevices of rocks. Thus Darwin tells us that during a century the island of St. Helena has lost a great number of species. Its flora, composed of 746 phanerogams, almost all of English importation, no longer comprehends more than 52 indigenous species: its ancient forests of different species, which extended over more than 1900 acres, have entirely disappeared, and several species have been utterly annihilated by goats and pigs; others are dangerously threatened, and botanists expect soon to have only the recollection of them. Even in Europe, where colonization has not suddenly changed agriculture and vegetation, plants have certainly ceased to grow in various countries. Thus the water-chestnut (*Trapa natans*) and the dwarf water-lily, which peopled the waters of Switzerland at the epoch of the lake-cities, are no longer to be found in that country. Certain regions of Ireland,

where the forest vegetation has been completely destroyed, either by man or by natural causes, still possess, under their incessantly increasing beds of peat-moss, fragments of pines and oaks; in the same way in the Shetland Islands trunks of a fir-tree, *Abies pectinata*, which is now completely wanting in the British Isles, and even in Scandinavia, have been found in the peat.

Besides, the experience of all the foresters and the testimony of history are amply sufficient to demonstrate that nature requires a continual change, an incessant rotation in the products of the soil. In all countries, if a forest be burned it is immediately replaced by other species; a "re-growth" of new trees springs from the earth instead of the old species, then after a certain number of centuries disappears in its turn to give place to the trees of former times; in the forests of Perche each of these re-growths lasts, on an average, from 290 to 330 years. Even when fire or violent destruction does not suddenly sweep away a forest, the latter does not the less transform itself in the course of centuries. According to M. Paul Laurent, a forest of Europe that in the Middle Ages consisted of beeches is to-day composed of oaks. Similarly, forests of oak, like that of Gerardmer, where Charlemagne went hunting, have been replaced by the fir and pitch-pine; the forest of Haguenau, now a pine-wood, was composed of beeches a century and a half ago. Finally, a number of localities which have formerly received the names of Charmettes, Pinasse, or Pinière, Châtaigneraie, Tremblaie, Boulaie, no longer have the species which have given them the name they bear. In the meadows also, M. Dureau de la Malle says that a rotation lasting for several years, is established between the graminaceous and leguminous plants. The vegetable populations are constantly changing; the life which germinates from the ground is, like the ground itself, in a state of perpetual transformation.

BOOK II.—THE LAND AND ITS FAUNA.

CHAPTER VII.

ORIGIN OF LIFE.—SPECIES OF ANIMALS.—MULTITUDE OF ORGANISMS.—CONTRASTS OF LAND AND SEA.

NATURALISTS have not yet distinguished precisely, amid the multitude of incipient organisms, the boundary which separates the plant from the animal. How many dubious forms there are! How many indefinite species difficult to class in one or the other systems of organized beings! Are they vegetables? They grow and are developed like them. Should they be classed among the animalculæ? They move and devour their prey. Placed, so to say, on the threshold of life, at the common origin of the innumerable generations which are born and die on the earth, they naturally appear to us as the ancestors of all the species more and more developed, which succeed each other in parallel series up to the tree and the mammal. For it is in them that, perhaps unconsciously, that special activity arises which in the higher organisms manifests itself with such great energy. Besides, we do not know what life is in those primeval shades where the germs are elaborated, where matter is disengaged from the rock or from the ooze, to change into little separate worlds. It is only by the consciousness of his own life that man can judge of that of other species: he takes his place proudly apart, and yet it is by bringing all into relation with himself that he establishes the series of living creatures.

The number of animals is probably not less than that of plants. The number of species is estimated provisionally at 260,000 or 280,000; but in reality it is unknown, excepting for the higher groups; and it is precisely these groups which are less rich in animals of different forms. The first class, that of the mammalia, is also distinguished from all the others by the least considerable number of representatives. Scarcely 1400 can be counted on the entire surface

of the planet, in the waters and on the dry land. According to M. Sélys-Longchamp, there would be in Europe only 121 species of terrestrial quadrupeds, and in this relatively small total it is the small-sized animals that form by far the greater number. In the same way of the 8000 varieties of birds known to naturalists, more than 5000 are of a size not exceeding the sparrow. The insects, much smaller on an average than the animals of all the higher classes, comprise in themselves alone more than 150,000 species, that is to say, about three-quarters of the whole fauna already studied by scientific men. And yet below the world of insects, crustaceans, molluscs, worms, and echinoderms, moves an immense swarm of animalculæ, which are at once the admiration and the despair of those who seek to investigate them by aid of the microscope. The organs of these wonderful creatures escape our sight, often even the drop of water in which they move and which is their universe is invisible to the naked eye; but they compensate for their smallness by the variety of their forms. Man can certainly attempt, thanks to method and accumulated observations, to enumerate the infinitely small species; but the task is hardly begun, and it is pursued with difficulty beyond the world of visible insects in that obscurity where only the thought of the mathematician seeking to apprehend atoms has penetrated. At all events, that which we already know enables us to recognize, at least from the mammal to the insect, a law of progression according to which the species are more and more rare in proportion as they rise in the series of beings. In acquiring complication of structure they lose in diversity of form; they improve, and become, so to say, a résumé of the inferior species, but at the same time they are more and more limited in number, as if nature required more strength to produce them. By a remarkable contrast, it is precisely the contrary that we observe in the vegetable world. There it seems that the numbers of species and individuals increase in proportion to their degree of development. The phanerogams have many more representatives than the cryptogams. The dicotyledons are more numerous than the monocotyledons, and in these two great divisions of plants with visible flowers it is the highest families, the graminaceous and composite plants, which are also the richest.*

If the multitude of species which constitute the whole of the earth's fauna does not yield in number to that of the flora, the host of individuals is equally innumerable; nothing more numerous can be imagined than the herbs and vegetables of every sort which clothe

* Schleiden, *Das Meer*, p. 165.

the surface of the earth. It is true that in consequence of their relative independence, animals are much less visible in nature, while vegetation forms a continuous carpet over the globe, and the green of the trees or the grass appears to us like the normal colour of the surface of the earth; animals, hidden under the verdure or in holes in the ground, seem at times to be completely absent from the landscape. On the other hand, the vegetables requiring a nourishing soil to support them only spread over its surface, while a number of animals can, owing to the freedom of their movements, be accumulated in enormous masses on the earth, or fly in clouds towards the sky, or else move in myriads in the depths of the sea. The atmosphere and the Ocean, no less than the surface of the earth, are the domain of animal life; it is only by millions that one can estimate the number of the passenger-pigeons of the United States, whose bands, traversing the sky with a speed of 50 miles an hour, take three days in passing by; it is by milliards that we estimate the grasshoppers which descend upon the provinces and cover them with blackish masses, glittering in the sun like a sort of cuirass, whilst they eat up all plants to the root. Finally, all calculation becomes impossible and imagination itself is powerless, when we would speak of the clouds of gnats which darken the air above the marshes of Louisiana and Columbia, or over the grand lakes of North America; and particularly when we think of the innumerable organisms which swarm in the Ocean. There is, therefore, an equilibrium, so to speak, between the two forces striving for the possession of the earth, between the flora and the fauna, the vegetable world and that which feeds on it.

The poets of former times, according to Homer, were pleased to give to the sea the epithet of "barren," and yet nothing equals its exuberant fecundity. Much more than the earth, of which the surface is only richly peopled, the Ocean is the domain of life. Not only its upper sheets, but also the deeper strata, are filled with organisms of every kind; in certain parts the myriads and myriads of creatures are crowded in such prodigious multitudes, that the waters themselves, so to say, are alive. There may perhaps be found in the vast watery tracts some deserts almost entirely destitute of life;* but these are exceptions, and in most of the regions of the sea every drop of water is a world from the multitude of beings that inhabit it. Taken as a whole, the Ocean may even be considered the special centre of life. It is in the waters, swarming with animalculæ, that continents are gradually formed, by the deposit of organic remains. New gener-

* Marcon, *Les Rochers du Jura.*

ations unceasingly at work lay the foundations of future continents. It is in the sea, too, as palæontologists tell us, that the primitive species must have originated, from which all the present forms, oceanic and terrestrial, are descended. The great basin of the seas is the cradle of life. "Water is the beginning of everything," said Thales of Miletus 2500 years ago.*

A long time ago Humboldt made the remark that the Ocean is, in contrast to the emerged lands, the principal centre of animal organisms, while the continents are in especial the domain of vegetable life. In fact, the waters of the sea often owe their colour and phosphorescent brightness to the numberless animalculæ which are developed there in prodigious quantities. Over immense extents the bottom of the Ocean, as discovered by the sounding-lead, is an animated ooze, each cubic inch of which contains millions of living creatures. The earth, on the other hand, excepting where in desert regions it is unprovided with water, is naturally covered with a carpet of verdure, plants, large trees, and innumerable parasites. The forests of polypes, in the South Seas, the polythalamia, which fall like snow from the surface of the water to the bottom of the Atlantic, the banks of herrings and *stromlings*, where the fish are as thick as the grass of the prairies, find their contrast in the seas of foliage, on the plains of the Amazon, in the undulating savannahs which stretch beyond the sight, and even in the cultivated fields variegated with so many different plants.

* Schleiden, *Das Meer*, p 121

CHAPTER VIII.

THE OCEANIC FAUNA.

The contrast between the land and the seas manifests itself also in the respective dimensions of their forms of life. The Ocean, so rich in infinitely small organisms, numbers also among its animals monsters far larger than those of the dry lands, while the greater part of its plants, and even those prodigious fuci several hundred yards in length, are nothing but simple strips, and present neither roots, trunks, nor branches which may be compared with the oak, the baobab, and the chestnut As to the organization, it is of the most rudimentary kind. With the exception of a single family of phanerogams, the marine algæ are all of the lower orders of plants without apparent fructification. The pelasgian plants have neither calyx, nor corolla, nor stamens, nor pistils. On the other hand, many animals are fashioned like flowers,* and the earliest naturalists were often deceived by them. For a long time the most learned among them, and even Reaumur himself, saw in these polypes real plants, and in our day many investigators have demanded if the algæ were not also, like the branches of coral, a kind of structure of vegetable form built by innumerable social animalculæ. In any case, it is certain that the generating granules of algæ move exactly like animalculæ, and, as it seems, "by an act of their own will;" they come and go, advance towards the light, and only fix themselves after having found the place that suits them in which to build their cellules. This is one more proof that the division between the two series, vegetable and animal, is in great part artificial.†

In their love of the marvellous, and perhaps also because of the terror which the sight of these monsters of the sea had occasioned them, our ancestors gave to these gigantic animals a size out of all proportion with their real dimensions. Numerous are the legends which speak of whales on which one could disembark as on islands,

* Schleiden, *la Plante.*

† Unger, de Mirbel, Paul Laurent, Payen.—Maugin, *Mystères de l'Ocean*

but which then plunged suddenly and left their visitors fighting with the waves. The seamen of all nations recount also a host of stories about monstrous serpents, which unrolled their rings over several large successive waves, and of polypes whose arms, incessantly in motion, resembled a forest agitated by tempests. The observations made by naturalists do not confirm these tales; but it is certain that whales have been measured more than 100 feet long and 65 feet in circumference, weighing nearly 200 tons, that is to say, more than an army of 3000 men. Scoresby saw a rorqual more enormous still, which was no less than 120 feet from head to tail. As to monsters of the size of the hippopotamus or the elephant, such as dolphins, orcas, cachalots, walruses, and sharks, the species are very numerous, and we often meet with individuals of this dimension in groups of hundreds and thousands in a limited space. Among the marine animals of an inferior order, such as cephalopods, there are some also of a prodigious size; thus specimens of the *Cyanea arctica* have been fished out of the bay of Massachusetts, 6½ feet in thickness and the arms of which were not less than 114 feet long.* And certainly it may be asserted beforehand that the Ocean still keeps in reserve many surprises for naturalists who will explore all its abysses.

Still, if the sea may be considered as the principal theatre of animal life, it is not so much because of the size and strength of its monsters as by the prodigious multitude of creatures which are agglomerated in rows, heaped up in banks, and swarm in immense beds. It is easy to imagine what innumerable armies of fish must fill the Ocean, since a single female may lay a hundred thousand, or million, or even more than ten millions of eggs. In the second generation a single couple of these fish may have given birth to a hundred trillions of individuals; in the third generation the entire sea with its unfathomable abysses would be filled with a compact mass of fish. But even before they are born this numberless progeny is pursued by equally numerous enemies. The sea is an immense field of carnage, where the creatures which are born in infinite myriads serve also as food to millions and tens of millions of furious devourers. When the herrings penetrate into the North Sea "it seems as if an immense island had risen, and that a continent was about to emerge;"† but this island or continent of fishes is beset and eaten on all sides. Each detachment of the mighty army, about thirty miles long and from five to six broad, is accompanied by legions of cetacea and other great sea animals, which

* Elizabeth and Alexander Agassiz, *Sea-side Studies.*

† Michelet, *la Mer.*

press in bands around the serried columns, and never cease swallowing herrings by hundreds; birds flying in clouds above the scene of the immense slaughter plunge down on all sides to select their victims; an oily substance resulting from the thousands of torn fish floats on the surface of the sea.* When at last the fishermen, warned of the approach of the bank of herrings, rush to their capture, the massacre assumes the most frightful proportions. The fishermen of the single district of the Goteburg kill as many as a hundred and fifty millions of herrings in a single campaign; those of Bergen three hundred millions; those of Yarmouth even more. The number of herrings captured during the fishery by the seamen of northern Europe must be estimated at tens of millions.

There are certain parts of the Ocean where the fish are still more numerous than on the coasts of western Europe; such is for example the bank of Newfoundland, where, in consequence of the meeting of two maritime currents, differing in temperature and the fragments they bring, all the conditions favourable to the development of a great diversity of species are found united. It is in the neighbouring seas that the Esquimaux, whose name signifies "eater of raw fish," finds his food in abundance; it is there that the fishermen, English, French, and American, go each year to seek their provisions from the two or three millions of codfish left by the multitudes of cetaceæ that are always at work. In the North Pacific, on the shores of Japan, round the Canaries are other fisheries scarcely less rich, whence the net is sure to bring each time numerous victims.

As to the marine animals other than fish, a number of species swarm in masses all the more compact the smaller the individuals themselves are. From the heights of the promontories, which rise in peaks above the gulfs of New Granada, to the east of Santa Martha, the sea is sometimes seen as far as the horizon filled with yellow medusæ, so crowded one against the other that the colour of the waters is quite changed by them. A swarm of medusæ, through the midst of which Piazzi Smyth passed in July, 1856, to the north of the Canaries, occupied a space about 45 miles wide, and comprehended in the superficial bed alone two hundred and twenty-five millions of individuals. Whales and other cetaceæ devoured enormous quantities of these graceful orange-veined medusæ, and, on their side, each of these animals absorbed myriads of siliceous diatoms. The quantity of these inferior organisms contained in the stomach of each medusa amounts certainly to seven hundred thousand, it is therefore by tens of

* Alfred Frédol, *le Monde de la Mer*.

thousands and by millions that we must estimate the creatures swarming in each wave.* Sailors, accustomed to see the innumerable multitudes of medusæ, only see in them "the scum of the sea;" and Bacon himself, that great observer, thought that the marine jelly-fish were nothing else than "heated foam." More poetically, the Peruvians of the coast of Iquique give to one of these animals the elegant name of *Aqua viva*,† or "living water."

Sometimes the sea is so filled with living organisms that one might call it saturated, and its colour is entirely changed by the floating multitudes. Thus on the coasts of Greenland seamen traverse broad bands of a deep brown or olive-green colour, being frequently 180 and even 250 miles long; they are banks of medusæ, every cubic inch of water containing hundreds, and swallowed by hundreds of thousands in every mouthful of a whale. Elsewhere navigators observe immense "sea-serpents" formed by innumerable salpas, which are attached to one another like the particles of one and the same body; or else they form expanses without visible limits, some red as blood, others white as milk. There they are not banks, but *worlds* of animals, where each drop contains as many as there are stars in the milky way. In August, 1854, Captain Kingman traversed in the Indian Ocean a space more than 25 miles wide, the whiteness of which was dazzling enough to extinguish the light of the stars; and when the sea of animalculæ was passed, the sky above it was for a long time seen to shine as with the light of a feeble aurora borealis. Ten years later the vessel *La Sarthe*, found again in the same part a vast "sea of milk," where the furrow of its prow made a black line.

Is not, however, the marvellous phosphorescence of the waters, due in great part to living animalculæ, the most astonishing testimony to the innumerable host of organisms which swarm in the Ocean? There is no voyager who has not observed during the night those sheets of yellow or greenish light which tremble on the sea, those sheaves of lightning which spring from the crests of the waves, those whirlpools of sparks which the prow of the vessel causes in its plunge, those waves of flame which glide from either side of the ship to unite in long eddies behind the rudder, and transform the track into a river of fire. In the port of Havannah the least object which agitates the surface of the water appears suddenly like a line of flame, and raises around it a whole series of luminous wavelets, pro-

* Piazzi Smyth, *Teneriffe*, pp. 5, 6.
† Bollaert, *Antiquities*, p. 256.

pagating themselves in concentric circles to several yards in distance. Boats sailing over these waters, driven by the equal movement of the oars, leave behind them the trace of an immense fiery dragon with large paws extended. In the Persian Gulf, Palgrave tells us that the waves are so luminous during the night that the Arabs attribute these reflections to the infernal fires shining through the rocks beneath the transparent mass of waters.* Modern science explains to us the phenomena of the phosphorescence otherwise. According to the researches of Boyle, Forster, Tilesius, and Ehrenberg, this light results from innumerable animalculæ, some living, and others in decomposition.

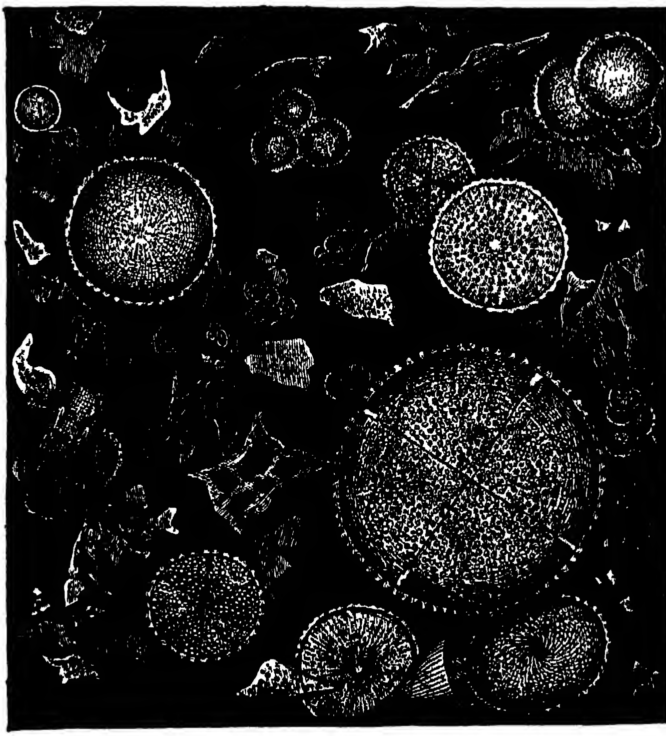


Fig. 174.—Organisms from the sea-bottom.

The little organisms called foraminifera, because of the numerous holes in their shells, are probably the creatures which people the

* *Journal of the Geographical Society*, 1864.

tracts of the Ocean in the greatest multitudes; the bottom of all the seas is, without exception, strewn with their thin calcareous shells, of which one drachm of sand contains sometimes nearly 16,000, according to a calculation of M. d'Orbigny. Among the various genera of this family, which comprehends nearly 2000 known species, the globigerina, which has an ovoid or spherical shell, may be considered as the special oceanic genus, since it is met with in all latitudes and at depths varying from 50 to 3000 fathoms. Their remains cover thousands of square miles of surface at the bottom of the Ocean; and when the lead brings up specimens of the ooze, it is often found that it is composed of 75, 80, or even 97 per cent. of the skeletons of a single species of globigerina.* The rest of the sediment is formed of other debris of little animals, spicules of sponge, and star-fish. Besides these, there are the siliceous organisms, the diatoms, which aid in filling up the marine depths. But do these bodies of such a perfect regularity, disks and triangles, parallelograms, pyramids, and other geometrical figures, all so gracefully ornamented with the finest arabesques, belong to the vegetable world? The botanist Schleiden believes so. Or are they rather animals? The zoologist Ehrenberg asserts it. But whether they be plants or animals, they are not the less one of the most important agents in the continuous formation of our globe.†

* Wallich, *North Atlantic Sea-bed* Parker and Jones, *Phil. Trans.* Vol. CLV. part I. 1865.

† See below, p. 174.

CHAPTER IX.

INFLUENCE OF CLIMATE AND PHYSICAL CONDITIONS ON THE SPECIES OF ANIMALS.

Animals, like plants, depend on all the conditions of climate; heat and cold, light and darkness, dryness and moisture, influence them in various ways, and give them a clearly-defined area of habitation. Nevertheless, a great number of species possess an advantage over the plants, for while these latter cannot fly spontaneously before an ungenial climate, and the displacement of their race takes centuries in accomplishing, animals, endowed with locomotion, can more readily migrate to countries which offer a temperature suited to them. Hundreds of species of birds and fishes, numerous tribes of insects, migrate every year, and are thus able, owing to the two countries which they inhabit by turns, to enjoy all the conditions of heat, light, and moisture favourable to their well-being. There are birds of passage, which travel several thousands of miles in a few days, and go from one continent to another over wide seas. Thus at the commencement of September the stork, dreading the severe cold of North Germany, abandons the thatched roof to perch on a cupola of Egypt or Tunis; then in the month of March, when the African climate becomes too dry and burning, it resumes its flight, and crossing the Mediterranean, passes the high Alps, either on the east by the Engadine, or on the west by the Jura, and alights once more on its nest, respected by the peasant.

In the climate of temperate Europe nearly a hundred birds, among them the crane, the lark, the passenger-pigeon, the quail, and the swallow, travel thus alternately from north to south and from south to north, to avoid the extreme temperatures, and perhaps still more to find an abundance of food at all seasons of the year; it is even possible that certain species cross the equator during the migrations, and by this coming and going they constantly enjoy a summer temperature, now in one hemisphere, now in another. Several species of mammalia make similar journeys: the vast prairies of North America witness each year the immense migrations

of the bisons, field-mice, and musk-rats defiling in innumerable multitudes. In mountainous countries, too, animals can easily change the climate without traversing vast spaces; it is enough for them to climb the mountain, and then to descend again to the plain. Some of the monkeys of Hindostan take refuge during the summer in the high valleys of the Himalaya, as far as 10,000 feet high, and return to the low forests of Terai at the approach of winter; in the same way the reindeer of Lapland follow the snow, which now accumulates, and now melts on the mountain slopes.

To avoid the extremes of temperature, either the cold of winter or the too great heat of summer, certain species of animals have also the resource of burying themselves in the ground. The greater part of the insects pass their existence as larvæ under the bark of trees, under heaps of leaves, or beneath the superficial strata of the earth. Some species of molluscs and fish, several reptiles, and a few mammals hide themselves also in the mud of the lakes and marshes, or in burrows hollowed out beforehand. Thus protected from the climate out-doors, the animals fall into a state of torpor, during which their life remains partially suspended; the temperature of their bodies sometimes sinks to freezing-point, and fish have even been seen completely frozen, without this apparent death having prevented their resuscitation later; respiration and circulation of the blood are gradually slackened, and digestion ceases entirely; the organs becoming temporarily useless are restricted; even the intestinal parasites are numbed with the animals upon which they live. This long period of sleep is, however, a phenomenon which is found much more generally in the vegetable world. For, in fact, all the plants of the frigid and polar zones repose in the winter, and only live by their stems and roots; even in warm countries, the plants present a remarkable periodicity in their existence.*

Although the privilege of locomotion permits a number of animals to enlarge their domain considerably, the species do not the less remain subject to climatal conditions, and all have an area of habitation limited either towards the pole by the severity of the cold, or towards the equator by too great heat. Each climate has its particular fauna, which, in order to live and propagate itself easily, requires certain normal conditions of temperature and moisture. There are animals which cannot quit the torrid zone without perishing, or living an artificial life like most of those transported at a great expense to our zoological gardens; other species die if they

* See above, p 106

are taken from the northern countries, covered with ice during the greater part of the year. The field-mouse seen by M. Martins on the Faulhorn, and certain amimalculæ such as the *Desoria nivalis* and the *Podura hiemalis*, have their dwelling in the snow, or on the ground covered by it. On the other hand, certain rotifers exclusively inhabit thermal waters; a Scarabæus, the *Hydrobius orbicularis*, lives in the sources of Hammam-Meskoutine, the temperature of which is 131°. In the seas the whale and various cetaceæ are arrested by the warm waters of tropical latitudes as if by a barrier of flame, while the cachalot and the sea-cow swim only in the tepid waters of the equatorial ocean.* In the same way the coral-insects are only seen in seas whose temperature is above 72° Fahrenheit; at 60 they can still live, but without developing their branches. The Gulf-stream, which carries into the northern seas the warm water from the Antilles and Bahamas, carries also with it multitudes of southern species, which never stray either to the right or left into the colder waters of the Polar current. The two masses of water flowing parallel to each other, but in an opposite direction, have each their distinct fauna, whose barrier of separation is an imaginary line between two zones of different temperature, varying according to the seasons and the advance of the waters. As to the superior animals which man brings with him into almost all the countries of the world, they are modified considerably under the influence of the climate. Horses and dogs brought from England to the Himalaya mountains are clothed with a thick wool that grows amongst their hair; in equatorial Africa, on the contrary, the dogs and sheep become bald, and fowls lose all their feathers, with the exception of the larger feathers of the wing.†

The influence of light is shown also in a very remarkable manner by the atrophy or even the complete suppression of the organs of vision in the fishes and other animals which inhabit the depths of caverns.‡ The colour of the skin, too, changes in most animals according to the brilliancy of the rays that shine on them. The fauna of caverns assumes a dusky and uniform livery, which is lost in the surrounding darkness, while outside in the splendour of the sunlight the brightest butterflies and birds fly, like winged flowers, no less brilliant than those of the meadow. The animals of the tropics, especially the insects, fish, and reptiles, shine in much brighter colours than those

* Maury, *Géographie de la Mer.*

† Schmarda, *Geographische Verbreitung der Thiere, Jahrbuch von Behm.*

‡ See in *The Earth* the section entitled, *Springs.*

of similar species from the temperate and glacial zones; thus, as M. Radau says, "the sun depicts itself in the fauna of a country." Finally, in the same individual the action of light manifests itself by the contrast of colours, glittering on the back or upper surface of the wings, duskier on the belly or the underpart of the plumage, which remains in the shadow. The habits of most species is also regulated by the alternations of light; mammals, birds, reptiles, fish, insects, and molluscs, have all their period of daily activity clearly defined, either by the setting or the rising of the sun. Among the insects especially, the awakening of each species by day, by night, or by twilight, is accomplished with a singular regularity. The mosquitoes of certain tropical regions succeed each other in the air at a fixed hour, well known by the natives, who, by imprisoning the insects which persecute them, are able to measure time no less easily than by that ingenious "Floral clock," where each hour is marked by the expansion of a corolla.

All the animals which inhabit the sea or the continents equally require air in order to live; but this air must be more or less pure, more or less charged with moisture, according to the species. Many birds, accustomed to rove through space, perish rapidly in the midst of a corrupted atmosphere, and even their eggs cannot be hatched there; the intestinal worms, on the contrary, and the innumerable species of animals which feed on decaying matter, and thus perform the office of scavengers in nature, can accommodate themselves very well to an air mixed with impure gases. Fish, too, and other aquatic animals, with the exception of the cetaceæ and swimming birds, directly respire oxygen dissolved in water. As to moisture, it is equally indispensable to life; but while certain species live on the borders of marshes or rivers, in an atmosphere loaded with vapour, there are others, especially the numerous tribe of lizards, which delight in the rock or dry soil of desert lands destitute of water.

The chemical composition of waters is most important for the organisms which live within it, and the fauna varies much in lakes, rivers, and seas, according to their proportion of salt and other substances; it is thus that the Baltic, the saltness of which at its entrance is the same as that of the Ocean, and which contains in its upper gulfs almost entirely fresh water, presents at its two ends two very distinct faunas, modified by gradual transitions towards the central part. As to the mineralogical nature of the soil, it has probably a somewhat slight influence on animal life, and the modifications which the fauna of the various soils exhibit, ought principally

to be attributed to the difference in the plants which serve as food to the animals. Thus some land-molluscs are found exclusively on limestone formations, because the substances necessary for the formation of their shells are not found in the vegetation of other districts. The physical conditions of the soil are also of great importance to the species which hollow out burrows or subterranean passages; the mole cannot trace its wonderful labyrinths in a sandy soil, which would fall in behind it, and the ant-lion which watches for its prey in a circular fosse, at the foot of hillocks of shifting sand, would perish of hunger if it ventured upon clayey ground. It is a strange thing that even the colour of certain species seems to correspond in a kind of secret harmony with the natural products around them. A humming-bird, that plunges with delight into an open flower, glitters like the flower itself; many fish which live in rivers with a sandy bed seem to be only thin flakes of spangled sand; moreover, a certain brown *mantis* of southern Africa lives only on a dark-coloured ground; another, entirely white, is only seen on the dazzling chalk rocks; the ptarmigan of Scotland is white as the snow in winter, and in the summer is dressed in plumage, whose shades of pearly grey blends with the delicate tints of the lichens and heather. The green leaves of our forests have for inhabitants the tree-frogs and other little creatures which match the verdure, whilst a butterfly itself, resembling a dead leaf, dances in the air among the dead leaves scattered by the wind; an orthopterous insect even seems as if it were disguised under the form of a broken beech-twig, and we might think that it was one of these innumerable fragments that the tempest has broken from the tree. On the river Amazon the air is filled at certain seasons with a species of white butterfly, flying in myriads like snowflakes in a storm; but amongst these butterflies are some individuals of species ordinarily distinct in colour, and which have disguised themselves in white in order to be lost in the immense crowd.* How can we attempt to explain this remarkable phenomenon, which constitutes the sole means of defence of the humming-bird, of the feeble insect, of the helpless parasite, excepting by the hypothesis of "natural selection" which Darwin has recently expounded so clearly? In the incessant struggle for existence, dating from the very origin of the species, all the individuals which cannot defend themselves by strength, cunning, scent, or venom, inevitably perish; those alone have the chance of escaping which, by their form and colour, are not distinguishable from surrounding objects. It is

* Bates, *Naturalist on the river Amazons.*

these, who by the gradual disappearance of the individuals visible to animals of prey, perpetuate the race, and in the succession of generations it is still the varieties most resembling the ground or plants on which they feed which save the species from destruction. Thus from generation to generation anomalies never cease to adjust themselves, and to assume in the end a permanent character.

CHAPTER X.

FOOD OF ANIMAL SPECIES.—CONTRAST OF FAUNAS.—AREAS OF HABITATION.—CHANGES IN THE SURFACE OF THE AREAS.—BIRTH AND DISAPPEARANCE OF SPECIES.

OF all surrounding circumstances that which most influences species, as we can easily understand, is their food. In the sea, where the flora is relatively poor and where the fauna, on the contrary, is developed with such an astonishing abundance, animals and animalculæ are almost all carnivorous; the herbivorous kind are few in number. On the dry land, on the contrary, the vegetation predominates so largely that most of the animals live upon plants, either their shoots, leaves, flowers, fruit, stem, bark, or roots. The largest animals, the elephant, rhinoceros, eland, and giraffe, as formerly the mammoth and the mastodon, feed on plants, grasses, and leaves. Most birds live on seeds, and with many of their species it is to the need of finding food, and not to the alternations of cold and heat, that we should attribute their annual or daily migrations. The life of the greater part of animals is only one long journey. Urged now by hunger, now by the necessity of seeking their safety, they come and go incessantly from one region to another, from the forests to the meadows, from the mountains to the plains, from solitudes to cultivated lands. In the valley of the lower Mississippi there is a kind of swallow, known under the name of martinet, which every morning flies in immense flocks towards the pine forests of the left bank of the river, and every evening returns and alights like a cloud on the marshy groves of cypresses on the right bank.

It is principally among insects that the intimate connection uniting the animal to the vegetable world shows itself. Many plants have their special fauna of insects, and of this eager multitude which devours them, some attack only the leaves, others the wood, or various other parts. The nettle has no less than 40 species which are born, live, and die on its stem. The birch, the willow, and the poplar are each also the exclusive home of numerous tribes of insects; the oak alone nourishes at least 184 species, more than the continent of

Europe contains in mammals; every other tree than that of which they eat the wood or the bark is an unknown world to them. Thus no insect of Cayenne has become a parasite of the cabbage, carrot, vine, or coffee-plant, because these plants have been imported from distant countries, and no corresponding species is to be found in the country.*

The area of habitation of each animal, large or small, which lives upon one or several vegetables, being necessarily limited by the area of the plants themselves, it necessarily results, that the carnivoræ are also quartered in the vegetable region which is inhabited by the prey that feeds them. Beyond the tropical zone in countries where winter periodically suspends the life of the forests and meadows, the parasites of trees and grass are also for the most part condemned to sleep, either in the earth or in the plant they feed upon, and the beasts of prey which have not a period of winter sleep must suffer hunger or change their country, till the return of spring. Finally, the destruction of a plant always has, as a direct consequence, the disappearance of the special fauna which was attached to it. If man fells a forest, uproots bushes, or drains a marsh, at the same time a world of animals is destroyed or exiled.

The richness of the fauna is thus in intimate connection with that of the flora: where vegetation springs from the soil with most vigour and abundance, there also animals live in the greatest multitudes. Nevertheless, we must not think that the animals of the largest size inhabit precisely those countries where the most gigantic trees grow. In this respect there is rather a contrast,—the great pachyderms of Africa feed on plateaux destitute of trees in many places, and covered with thin grass; the enormous white bear of the northern regions inhabits snow and ice-fields, far from all forest vegetation. On the other hand, the splendid forests of Brazil give shelter to relatively small species; the largest is the tapir, much inferior in dimensions to the huge animals of Africa. The most remarkable fact in the distribution of the largest species of animals is, that they inhabit the most extensive countries; it is in the Old World that the largest members of the animal world live; and the long-tailed monkeys, tapirs, vicunas, jaguars, and pumas of America are much less in size and strength than the gorillas, elephants, camels, tigers, and lions of Africa and Asia.

The number of species of animals is likewise connected with the extent of the countries. There does not exist one example of an

* Schmarda, *Geographisches Jahrbuch von Behm*, 1866.

island whose fauna is richer than the neighbouring continent,—in almost all we find an enormous inferiority in this respect. Great Britain, a fragment detached from Europe, has fewer animal forms than Germany or France; Ireland has less than England; Sicily less than Italy. When the Europeans first landed on the Antilles, nearly four centuries ago, the sole indigenous mammals, with the exception of bats, which could fly over the straits, were four or five species of rodents, one of which exists still. Yet the very varied vegetation of the mountains, valleys, plains, marshes, and shores of Cuba, Hayti, and Jamaica, would have sufficed for the support of a multitude of species. In the same way, before the arrival of the English navigators, New Zealand had no other mammals than two species of bat, a rat introduced, perhaps, in a ship, a sort of otter, and a leaping animal, only the remains of which were seen.* A real harmony is naturally established between each region and its particular fauna so completely, that the geologist discovering very varied fossils and large skeletons in an island of small dimensions is able to affirm that it once formed part of a vast continent.

In order to resolve the important question of the distribution of animals, the naturalist must go back to the anterior ages of the earth, during which the continents were otherwise disposed than they now are. Thus the monkeys on the rock of Gibraltar bear witness to the ancient continuity of the coasts between Spain and Barbary. In other places, in consequence of the change in the forms of the continents, the former species contrast strangely with the present ones; only a strait separates two fauna, born at an interval of thousands and perhaps millions of centuries. This is the contrast observed between the archipelago of Sunda and the group of the Australian islands. Between Bali and Lombok, which seem, however, to form part of one land cut in two by the waves, and which a strait, 15 miles long, scarcely separates, the contrast of the faunas is as complete as between Europe and America. On one side quite modern species live, as if the ancient types had been gradually renewed by the neighbourhood of the vast continent of Asia; on the other, the animals have been preserved without a change in their physiognomy. In Australia we find neither cat, wolf, bear, nor hyæna; neither stag, sheep, ox, elephant, horse, squirrel, rabbit, nor any of those species of quadrupeds which we meet with in all other parts of the earth; but instead, how many animals of ancient forms, which to us seem most strange! The whole Australian fauna re-

* F. von Hochstetter, *New-Seeland.*

sembles that which formerly occupied the seas and shores of Europe during the Jurassic period; it is necessary to trace the course of the ages back to that epoch, to find animals which recall those of New Holland.*

Whatever may be the enormous part to be referred to the earlier conditions of the globe to explain the present distribution of the animal species, it is certain that there is now a remarkable harmony between the configuration of the continents and seas, and the crowd of living creatures which inhabit them. Every terrestrial or maritime space, clearly limited by some great geographical feature, such as a strait, isthmus, mountain-chain, or plateau, every district distinct from the countries bordering upon it by the nature of the soil, and especially by the climate, possesses also its peculiar fauna, having but a relatively small number of representatives in common with those of other regions. The French plains which stretch to the north of the Pyrenees, and the Spanish valleys of the tributaries of the Ebro, contrast with each other in a sufficiently striking manner, both by certain species of animals and by their vegetation and the general aspect of all nature. Similarly, the difference is very great for the living organisms as well as for the soil on the two slopes of the Alps; in France, in the stony and desolate basins of the Drac, the Durance, and the Verdon; in Italy, on the fertile banks of the Stura, the Po, and the Doire. A narrow isthmus, separating two seas, separates at the same time two worlds of different species. It is thus, that of one hundred and twenty zoophytes, the Mediterranean has only two in common with the Red Sea, and yet the slight sandy barrier of Suez is of relatively recent formation in the immense series of geological ages. The slender isthmus of Central America, which lies between the Pacific and Atlantic Oceans, is an insurmountable barrier to the two faunas, and the waters separated by a distance of a few miles only are inhabited by totally different species; there scarcely exists, Darwin tells us, a single fish, mollusc, or cetacean, which is common to the two oceans. Even the course of the river Amazon serves as a limit to multitudes of species; there are birds which never venture to cross it, and whose area of habitation is strictly limited either to the right or left bank.

In consequence of the great diversity of the present conditions of climate, soil, and food, in consequence too of the infinite multitude of causes, which, in the earlier ages, may have favoured or hindered the development of the species engaged in the struggle for existence,

* Wallace; see in *The Earth*, the section entitled, *The Earliest Ages.*

the areas occupied by different animals are most unequal in extent. There are cetaceæ, swimming birds, and echinoderms, which live in all the seas, and gnats, which fly in clouds over the marshes of all the continents; on the other hand, certain species are only found in a very limited region. Some reptiles are peculiar to a single district of the Rocky Mountains or the plateau of Utah; a certain humming-bird has been discovered in only one valley of the Andes; every lofty volcano of Ecuador, as Pichincha, Chimborazo, and Carahuirazo, is a separate world, having its own special fauna.* In the immense river Amazon three species of a fish called *arias* are found only to the west of the island Marajo, in a space of scarcely two leagues, at the place where the mingling of the mud raised by the conflict of the sea and river takes place.†

Besides, the different areas of habitation change incessantly during the course of ages according to the modifications of soil and climate. Man, too, who is also a geological agent, and one of the most active, has taken an enormous part, either directly or indirectly, in the distribution of animals; ‡ but apart from this decided influence due to human intervention, it is certain that all the variations of the surrounding circumstances produce corresponding variations in the distribution of species. If cold or heat increase in a country, the winds become stronger or weaker, the rains increase or diminish; or if the soil be renewed by alluvium, or saturated with salt by an irruption of the sea, or if a marsh be formed or dried up, a number of species of animals will advance or retreat to find conditions of existence which are more favourable to them, and also to seek food which suits them. Thus various birds of the upper Engadine have established themselves in the lower valleys, and the magpie has even entirely quitted the district.§ This is a phenomenon which all naturalists have observed: they have even ascertained many apparently inexplicable examples of migrations, so imperceptible to man have been the modifications of circumstances which have produced these changes in the areas. Thus the whales ceased to visit the Färoe Islands for 22 years, from 1754 to 1776; in Sweden a number of species have completely disappeared from the country, and have then returned like exiles re-entering their native land, to inhabit again the country of their ancestors.|| Nor is this all: not only may

* Moritz Wagner. † Da Silva Continho.

‡ See below, the section entitled, *The Works of Man.*

§ Michelet, *la Montagne.*

|| Schmarda, *Geographisches Jahrbuch von Behm*, 1866.

animals enlarge or restrict their areas of habitation, but they may even completely disappear, and zoological history, hardly commenced a few centuries ago, already has to relate the extinction of several species. On the other hand, new creatures take the place of those that have departed, and during the succession of ages the fauna is renewed by the formation of varieties, which become more and more constant, and at length present all the characters of species. How otherwise can we explain the remarkable fauna described by Darwin, which belongs especially to the Galapagos Islands, and is neither found in the archipelagos of the South Sea nor on the nearest continents?

CHAPTER XI.

GREAT TERRESTRIAL FAUNAS.—HOMOIOZOIC ZONES.

EVERY district distinguished from those that surround it by a certain number of animal forms, has thereby a special fauna; but naturalists usually take this word fauna in a more general sense, and apply it to a collection of species inhabiting a vast geographical region, beyond which the majority of forms are completely changed. For the rest, as might be expected, savants are far from agreeing on the limits of these regions, for these frontiers have no real existence, and in the multitude of living creatures, whose areas of habitation mingle with and intersect each other, there are several which belong at the same time to many districts. Schmarda, one of the most eminent classifying zoologists, enumerates 21 great terrestrial faunas, including those of Madagascar, the Sunda Islands, and Oceania. These various zoological provinces, each one of which possesses only a small number of species in common with the neighbouring provinces, have still many points of resemblance with each other, owing to the multitude of animals which approach each other in form and structure, and fulfil analogous functions in nature; these species, which in the fauna of a continent take the place occupied in a different country by other animal forms, are termed scientifically representatives. Thus the camels of the Old World are replaced in America by lamas and vicunas; the horses of Asia have the zebras as relations in South Africa; the ostriches of the Sahara are represented in Australia by emus, and in the Argentine pampas by rheas. In this respect the animal world presents the same harmonies as the vegetable world.

The greatest analogy between the two organic series is found also in their order of distribution over the circumference of the globe. All the circumpolar regions of the northern hemisphere in America, in Europe, and in Asia, are inhabited by identical species, or at least present a great appearance of relationship to each other; the same flora and the same fauna occupy the extremities of the continents;

but towards the south, in proportion as the lines of latitude enlarge their circles, and the Old and New World withdraw from each other, the living creatures that people them, animals and plants, differ more and more. The number of organisms common to the lands separated by the Atlantic and the Pacific Oceans gradually diminishes, and in the tropical regions the contrast between them is complete. At the same time, animal and vegetable species become more and more numerous in the direction from the pole to the equator. In Spitzbergen, M. Charles Martins found only four terrestrial mammals; 22 species of birds, all of them being migratory with one single exception, flying beyond the mountains of this archipelago; 10 sorts of fish inhabit its coasts, while the lower orders of animals are represented by only a very small number of forms: only 23 insects and 15 molluscs have been discovered there. To the south of the northern regions the number of species, genera, and families is multiplied ten-fold or even a hundred-fold; and in the equatorial countries, where vegetation exhibits all its luxuriance and wealth, the fauna shows also a marvellous variety of organisms, and its types are of the most beautiful and dazzling colours. A single naturalist, Bates, after a stay of eleven years on the banks of the Amazon, brought back a zoological collection of 14,712 animals, 8000 of which were new to science. How many must still remain to be discovered, especially among the insects and Annulosæ. According to Agassiz, the Amazon alone possesses three times as many different fish as the immense basin of the Atlantic.

It is true that if the countries nearest the pole are poor in species, these species themselves are for the most part represented in immense numbers. On all the promontories and in all the fjords of the Hebrides, the Shetland and Färoe Islands, Norway, Spitzbergen, and Nova Zembla, the shelves of rock, similar to the shelves of an amphitheatre, are occupied, far as eye can see, by ranks of birds, crowded together like an army of soldiers. When these prodigious flocks of birds set off in search of prey they rise like clouds, and man has only to shoot at hazard in order to strike down his victims; unless armed with a stick he prefers to despatch the females, which, screaming with rage, remain devotedly covering their broods.

The Oceanic faunas must necessarily present a greater regularity in their distribution than the terrestrial faunas, for they are not liable to such changes in physical conditions as affect the surface of the land. The sea is not, like the land, full of obstacles which check the distribution of animals, and modify, in various ways, the configuration of

their domain. Thus the limits of each great maritime fauna are precisely those of the basin where this fauna is developed; to the east and west they are the shores of the continents; to the north and south they are the different climates which arrest the species, and cause them to be succeeded by other animal forms.

Edward Forbes was the first who attempted to draw a map of the distribution of living organisms in the seas, and since then the general results which he indicated have been confirmed in great part by the various savants who have followed him in this way. Each region or maritime province is characterized by species which may serve as representatives of all the other organisms of the province, and which attain their greatest development in these parts. From all sides of the central zone, where the fauna peculiar to the province shows itself in all its richness, the species go on diminishing by degrees towards the other regions, and are finally replaced by the prevailing species which in this portion of the sea constitute the bulk of the marine population. Forbes compares the domain of each of these fauna to a nebula, the luminous points of which, united in the centre in a brilliant mass, become less and less numerous as they diverge from the centre, and on the circumference constitute nothing more than scattered traces. The Oceanic fauna, consisting as they do of a series of zoological nebulæ, do not, however, differ in this respect from the continental fauna; but, owing to the facilities for migration afforded by the sea to free-swimming animals, the maritime provinces in which any particular species predominates are wider in extent than in an analogous district of *terra firma*. Generally speaking, places situated in the same latitudes are frequented by the same species; a remarkable instance of this fact may be observed in the Mediterranean, where, from Gibraltar to Alexandria, there is scarcely any difference in the marine fauna. With regard to the limits of these regions common to the same groups, their extent can very seldom be clearly defined, except where ocean currents of different temperatures come into contact. The change from one province to another generally takes place without any sudden transition, for the action of currents, tides, &c., endeavours incessantly to establish an equilibrium in the temperature of the Ocean, and prevents any well-defined boundaries of the limits of any forms of life.

It is, nevertheless, necessary to take into consideration every condition which tends to modify the general outlines of each geological province, the form of its sea-coast, the nature of its bed, the rapidity

of its currents, the height of its tides, and the saltness of its water.*

These various provinces are the extensive regions which Forbes has designated by the name of homoïozoic zones (zones embracing a similar kind of life). They encircle the earth like the climateric zones to which they correspond, and, speaking generally, their limits are formed by the isothermal lines; they also change their position in harmony with these ideal limits, sometimes rising towards the north, and at others curving towards the south.

The great median zone is that of the equator and the tropics, the most important part of which comprises the whole of the Indian Ocean and the central belt of the Pacific, from the coasts of Australia, Borneo, and Japan, to those of Mexico and Columbia. In this region, for the most part, marine animals present the most brilliant colours and varied forms. This, too, is the region where the waters swarm with the greatest number of organisms, and corals and madrepores construct their circular islands, which stud the coasts of Asia as far as the middle of the Southern Ocean. Between equatorial Africa and America this homoïozoic zone is still continued in spite of the interposition of two continents; on the coasts of Florida, the Bermudas, the Antilles, the Guianas, and Brazil, molluscs, echinoderms, and corals, similar to those of other equatorial seas, multiply abundantly; the species are different, but the general types are the same.

To the north of this median zone, which extends round the globe with an average breadth of 3700 miles, there is another encircling zone, which is much narrower and rendered very irregular by the variations of climate which towards the north are produced by winds, maritime currents, and the different conditions of the opposite continental coasts. This northern "circumcentral" zone takes its rise in the Atlantic on the coasts of Georgia and the Carolinas, then spreading out towards the east, it washes the coasts of Morocco and of the Iberian peninsula. Beyond the straits of Gibraltar it embraces the Mediterranean, where there are fisheries for the tunny, sponge, and coral. In this sea the species show a gradual diminution from west to east, and in the enclosed basins in the interior of the continent, the Black Sea, the Caspian, and the Sea of Aral, they are even much less numerous. In the Pacific, this same zone, the limits of which are however scarcely known, stretches from the coasts of the Corea and Japan towards those of California.

The third zone, which is situated about the middle of the temperate latitudes, has received the name (not however a very appropriate

* *Natural History of the European Seas.*

one) of the neutral northern zone. Like the last-mentioned zone, it curves round and spreads out across the Atlantic from the coasts of America to those of Europe. It is narrow along the shores of Virginia and Delaware, but it widens out towards the north-east with the Gulf-stream, and embraces all the Celtic seas of the peninsula of Brittany, Ireland, Scotland, and the Shetland Isles. The Baltic Sea and its gulfs are mere dependents on this zone. The great herring fisheries are carried on in this homoiozoic zone.

The most northerly zone which is characterized by fisheries for cod and other fish of a similar nature, likewise follows the immense curve of the Gulf-stream, and stretches from east to west. Beginning at Cape Cod in the Bay of Fundy, it embraces Iceland and the adjacent seas, and washes the coasts of Norway and Lapland up to North Cape. In the Pacific this zone, known as the northern circumpolar zone, assumes, like the neutral zone, a circular tendency owing to the great current of Japan and the south-west winds, which in this part of the ocean bring about a circuitous movement similar to that of the Gulf-stream.

Lastly, the Arctic Seas are occupied by the polar homoiozoic zone, the extent of which comprises the whole of the spherical cap from the Pole to Labrador, the Gulf of Obi, Behring Straits, and Kamschatka. In this region the inhabitants of the sea generally speaking are of rather dull colours, and the species are much less numerous than in the southern zones; but on the other hand, these species are for the most part represented by a great number of individuals.

In the southern hemisphere, the homoiozoic zones follow one another in the same order as in the opposite hemisphere, and exhibit similar transitions between the respective typical species; but, it must be confessed, the comparative extent of these various zones is very imperfectly ascertained. All we positively know is that to the west of South America, the domain of each of the marine faunas curves round towards the north, carried away, so to speak, by "Humboldt's current," which runs along the coast. For the present, the lines of temperature are the only *data* we have for fixing, somewhat inaccurately, the limits of zones: it will be the task of future explorers to determine them more exactly. It would be equally difficult to state at the present time in what proportion species of marine animals diminish from the equator to the poles. In order to solve this question approximately, it would in the first place be necessary to ascertain the quantity of organic beings contained in the various

oceans. All we positively know is, that in the European seas, the species of fish show a diminution of nearly two-thirds in the northern as compared with the southern seas, since in the Mediterranean 444 are met with, while in the Scandinavian seas there are found scarcely 170. Molluscs resist better the influences of climate, for about 300 have been reckoned on the coasts of Sweden and Norway, that is to say, nearly half as many as on the shores of the Mediterranean.* During the only voyage of discovery conducted by Captain Wilkes, the American naturalists succeeded in collecting in the tropical waters of the South Sea 829 species of fish, 900 crustaceans, 2000 molluscs, 450 corals, and 300 zoophytes.

* Forbes, *Natural History of the European Seas.*

CHAPTER XII.

DISTRIBUTION OF SPECIES ON THE SLOPES OF MOUNTAINS AND IN THE DEPTHS OF THE SEA.

The gradation of climate on the slopes and heights of mountains, similarly to their succession in the direction of the poles, brings about, as its necessary consequence, a rapid diminution of animals from the fertile plains at the base to the snowy summits of the mountains. If the naturalist scales some solitary lofty peak in the torrid zone, he will see the number of animal species rapidly diminishing, exactly as if he were travelling towards the temperate regions, and then towards those of the pole. At last, when he reaches the lower limit of perpetual snow, where vegetation almost entirely disappears, there remain but very few representatives of the animal world, and those which still exist in these upper regions are mostly minute beings, like the animalculæ of the snow, and small quadrupeds which bury themselves in the snow, similar to the *vole*, which is met with on the summits of the Alps.* Not only do the species gradually diminish on the slope of the mountain, a fact, however, which is easily accounted for by the deficiency of food, the increase of cold, and the rarefaction of the air; but also the animals met with in the upper regions are not the same as those of the lower slopes, and in their form, coat, and habits resemble the animals of the polar zone. The faunas of the Andes and the Alps bear more resemblance to those of Spitzbergen than to those found in the plains at their feet, which are situated at a distance of a few thousand feet.† Nevertheless storms, gusts of wind, and water-spouts frequently blend the locally arranged faunas one with another, and as we traverse the snow on the summits, we rarely fail to see the great white surface dotted over with the remains of insects which have been carried up from the valleys by atmospheric currents. Sometimes even a few stray butterflies fly by chance into these gloomy solitudes, where the

* Charles Martins, *du Spitzberg au Sahara*, p. 340.

† See above, p. 123.

cold during the night is certain death to them, unless some favourabl wind carries them back to the warmth of their native meadows. As far as birds are concerned, numbers of them fly freely up to the loftiest summits. M. Jules Remy has seen myriads of humming-birds flying noisily round the crater of Pichincha, and the traveller, scaling the proudest heights of the Andes, sees far above his head the great condor soaring majestically in the blue sky.

On dry land most animals inhabit districts but slightly elevated above the level of the ocean; following the same rule, a large majority of the inhabitants of the seas, infusoria, annelids, crustaceans, fish, and other creatures, exist in the liquid strata of the surface and in the neighbourhood of coasts. This must be the case, for it is only along the sea-shores that we find rocks which are covered with shells, caves, and crevices, where the fish take refuge, and also the forests of sea-weed, which are used both for shelter and food by multitudes of organic beings; there, too, the rivers convey all the animal and vegetable debris from the main-land, which serves as food for the inhabitants of the sea. Further out to sea every stray piece of sea-weed and every floating mass of the same is also a mustering point, round which a perfect little world lives and moves; even far from the shore and shallow water, life although less stirring in comparison with that of the coast, is nevertheless wonderfully active in the upper strata of the sea, for there the waves take their rise on the surface, and their movements are as necessary to the organic beings of the sea as the breath of the wind is to the life of terrestrial animals; these upper strata are also the portions of the Ocean into which the light penetrates. According to the experiments of Wilkes, the rays of light would not descend beyond 82 fathoms, and this point, therefore, would mark the limits determined by the darkness, habitable by marine animals and vegetables. Therefore the zone of contact where the sea meets the atmosphere, and especially in the vicinity of continents, is where aquatic life swarms in the greatest abundance. On land, the conjunction of several geological strata fertilizes the soil, and consequently promotes a greater degree of activity in the development of the different germs; in the same way, the contact of the three elements, water, wind, and shore, draws organic beings into the surface-strata of the Ocean, and thus enfolds the globe as it were in a living envelope.

The shallow parts of the sea, especially in the vicinity of the coasts of Europe and the United States, have been already explored with the greatest possible care by Edward Forbes, in order to point out

the approximate depth of the superincumbent layers of flora and fauna. Each of these zones is distinguished by organisms or groups of organisms peculiar to it. They do not, however, with the exception of the upper strata, present any clearly-defined boundary; there are, moreover, a great number of genera and sub-genera, which are common either to all the elevations, or to two or three of them.

The first zone, or that of the shore, is limited by the extreme lines of ebb and flow, and according to the height of the tide is from half a fathom to 11 fathoms in depth; in this stratum a multitude of organisms live and move, because it is in turn occupied both by the water and the air. The second stratum, called the laminarian zone, from a species of sea-weed which there throws out its long band-like leaves resembling leathern straps, has a depth of about 16 fathoms below low-water mark. This is the principal habitat of marine plants, fish, molluscs, and crustaceans. Most of the species found here are remarkable for the brilliancy or even splendour of their colours, which they owe to the luminous rays refracted from the surface of the water. The third, or coralline stratum, extends as far as 32 fathoms below the last-mentioned stratum; vertebrate or invertebrate animals are here represented by numerous species, but vegetation begins to be scarce. The fourth stratum of the European seas, which, according to Edward Forbes, has not a depth of more than 110 to 330 fathoms, and beneath which extend the vast solitudes of the uninhabited seas, is without doubt less thickly populated than the body of water above it, into which the light of the sun succeeds in making its way, and the molluscs, crustaceans, and annelids which are found there are for the most part of a sombre hue; but even at this point we have not reached the limit of life.

It is an indisputable fact that marine animals exist at a much greater depth than naturalists until very recently allowed. Although soundings taken at great depths in the open sea have not at present been very numerous, and though in most cases the sounding line did not bring up any traces of sand or mud from the bed, most savants, relying solely upon this negative evidence, predicated that the lowest depths of the Ocean were abiotic spaces, that is to say, absolutely destitute of living organisms. Even when several mariners had obtained proofs to the contrary, many well-known savants, such as Edward Forbes, Godwin-Austen, Agassiz, de la Bèche, were still of opinion that below a certain depth, fixed by some at 165 fathoms and

by others at 330 fathoms, all animal or vegetable life was impossible. Each depth of five and a half to six fathoms involving a pressure of water equal to that of an entire atmospheric column, it was thought that the general proximate conditions would be so changed at the bottom of the Ocean, that the development of any organisms in these vast depths would be rendered absolutely impossible. It was also a foregone conclusion that living beings could not live under a pressure of hundreds or perhaps thousands of atmospheres. According to an hypothesis which is just as much in opposition to the facts, neither plants nor insects can exist on the highest mountains; in the same way, by a kind of polarity, the bed of the Ocean was supposed to be nothing but a vast solitude. The hardiest among marine animals would then be the fine coral of the coasts of Norway, the *Lophelia prolifera*, the rose-coloured branches of which are found attached to rocks at a depth of 330 fathoms from the surface.

Nevertheless, since the year 1818, the results of many soundings have contradicted the opinion laid down by most naturalists. In Baffin's Bay John Ross brought up from the bed of the sea some small crustaceans, annelids, and echinoderms, and in the regions inhabited by these animals the depth determined by the sounding-line varied from 110 to 1033 fathoms. On the other side of the globe in the Antarctic Seas, James Ross discovered in 1814 some living crustaceans at a depth of 393 fathoms; but this fresh evidence verifying the existence of organisms in the lowest depths of the Ocean was ignored like the former. Some time after the soundings made between Ireland and Newfoundland along the "telegraphic *plateau*" brought to the surface a large number of small organisms, foraminifera, polycistina, and diatomacea. Further, the sounding-line brought to light 116 different species of these animalculæ, taken from a depth of 3660 fathoms between the Philippine and Ladrone Islands.

Lastly, in the voyage of exploration undertaken by McClintock in 1860 across the North Atlantic, Dr. Wallich definitely solved the question by indisputable proofs. At the south-east of Iceland the dredge detached a fragment of a serpula, the flesh of which was still fresh, and some small living shell-fish, from a rock at a depth of 671 fathoms. In addition even to this, another sounding, made at a depth of 1240 fathoms, that is, at a point where the weight of the body of water exceeded 200 atmospheres, brought up several small shell-fish and thirteen star-fish, one of which was not less than four and a half inches in breadth: these animals reached the surface of the water alive, and for a quarter of an hour they incessantly worked

about their long spike-covered arms;* besides, the remains of the foraminiferæ which were found in the digestive organs of the echinoderms allow no doubt as to the fact that these inferior organisms likewise exist at a depth of more than 1200 fathoms in the ocean. Since Dr. Wallich's discovery, Torrell brought up from a depth of 1430 fathoms in the sea of Spitzbergen a crustacean of brilliant colours. The same fact applies to the Mediterranean, for when the telegraphic cable which joins the island of Sardinia to the coast of Genoa was broken, its fragments were found to be covered with polyps and shell-fish, bringing the wire in some places to the size of a hogshead. Subsequently, the submarine telegraph between Sardinia and Algeria was also broken, and Mr. A. Milne Edwards recognized on a fragment of the cable, fished up from a depth of 1000 to 1500 fathoms, a large number of animals, which must all have existed in the bed of the sea on this wire laid down by human agency; for their forms were moulded round the iron on which they rested, and their soft parts were still in a state of preservation. Among these creatures there were found serpulæ, a species of oyster, a highly-coloured pecten shell, and lastly, some polyps which hitherto had not been met with in any part of the Mediterranean, and were thought to exist only in a fossil state.† This is not all: Ehrenberg has shown that luminous animalculæ exist at the bottom of the Gulf of Mexico, and this unexpected fact admits of the supposition that the depths of other seas and of the vast ocean are not lost in unfathomable darkness. It may therefore be concluded that at a depth of even thousands of fathoms light is not altogether wanting, and that it shows itself periodically, or even constantly, thus explaining why the eyes of species taken from deep waters are not atrophied like those of fish and insects found in dark caverns.‡

Thus the depths of the ocean are not a vast desert where the movement of hidden counter-currents is the only evidence of terrestrial life; even in the midst of these regions, where a ray of light never penetrates, there are beings which are born there, which live there, and which there find their graves. Doubtless, most of these beings, like the inhabitants of caverns on *terra firma*, are dressed in a sombre hue; but this is not a zoological law, for those very species which have been discovered at the greatest depths, namely the echinoderms,

* Wallich, *Atlantic Sea-bed*, p. 69.

† *Annales des Sciences Naturelles*, 4th series, 1861.

‡ *Mittheilungen von Petermann*, vi. 1867.

found by Wallich in the sea of Iceland, and the crustacean taken by Torrell from the bed of the Frozen Sea, present tolerably bright colours. By gradually adapting themselves, either by migration or by the effect of a slight depression of the bed, to their location in these deep waters, these creatures have preserved the specific brilliancy of their colour, which their ancestors doubtless owed to the vivid light with which the superficial strata of the ocean are imbued.* As far as marine plants are concerned, sea-weeds properly so called have not yet been noticed growing at a depth of more than 218 fathoms: the only organisms which could be called vegetable which have been found in the depths of the ocean belong to the primitive order of diatomaceæ.

$_*$ Still more recent dredging researches, carried on by Carpenter, Wyville Thomson, and Jeffreys in England, Count Pourtales in the United States, and Sars in Sweden, in depths varying from 200 to 650, and even up to 1400 fathoms, fully justify the inference that there exists a varied and abundant submarine fauna, at depths which had generally been supposed to be *azoic*. They also completely disprove the earlier doctrine that an increased amount of bathymetric pressure must be prejudicial, if not fatal, to higher forms of animal life.

The presence of bright colours in shells and crustaceans obtained from these vast depths, almost certainly proves that light—though greatly modified—does penetrate even to the inmost recesses of the deep sea.—H. W.

* Wallich, *North Atlantic Sea-bed*, p. 135.

CHAPTER XIII.

GEOLOGICAL LABOURS OF CERTAIN ANIMAL SPECIES.—CORAL REEFS AND ISLANDS.

There are very few animals which, in order to obtain their prey or to construct their habitations, disturb the ground so forcibly as to leave, either on the surface or in the upper strata of the earth, traces of their work. Rabbits, foxes, "prairie-dogs," and marmots dig out burrows; moles and musk-rats make their way under-ground, like miners, through long avenues or labyrinthine galleries; white ants construct "high obelisks of clay;" but when the animal-builders have left their hidden vaults or visible palaces, they do not long resist the rains, vegetation, and all the other agents of destruction which surround them. Among works directly accomplished by mammals, those which last the longest and may exercise a real influence on the topography of a district, or even its local climate, are the structures made by the beaver; rivulets kept back by these dams are changed into marshes, or perhaps take a different course, and sometimes even become tributaries of another basin. At the time when the forests of Western America were still inhabited by vast tribes of beavers a large number of watercourses were thus changed, by the trunks of fallen trees, into a succession of pools. Even in our time nearly all the streams which flow to the east of the mountains of British Columbia have been dammed up and changed into marshes. The beavers have themselves destroyed the watercourses which were necessary to their existence.* The worm disturbs the ground to more purpose, for although the work done by each individual may amount to very little, the result of the collective labour is nevertheless of the greatest importance; for, as Darwin points out, it is the earthworm which most contributes towards preparing the vegetable soil on which we till.

In the enormous geological changes caused by animal life, the creatures themselves have taken no voluntary part, and if they modify the face of the planet it is solely owing to the accumulation

* Milton and Cheadle, *Voyage de l'Atlantique au Pacifique.*

of their debris. The humble sphagnum, and other marsh plants, owing to their innumerable multitude, ultimately spread thick layers of peat over vast plains and even on mountain-slopes, and in the same way the very smallest animalculæ multiplying by myriads and myriads at length form immense strata in the outer crust of the earth. One quarter of the town of Berlin is built on loose soil composed of successive generations of these infinitely tiny creatures; at the mouth of the Oder and many other rivers, in the port of Wismar, and on the bar of Pillau, a third, or even a half of the mud is formed of living species accumulated in incalculable numbers;* the mass of animalculæ which every century is deposited in the port of Pillau must at the very least be estimated at more than a million cubic yards. This mud will some day dry up, and, like schist and sandstone, form solid strata in the plains and mountains of *terra firma*. In the same way diatomacea and foraminifera from the bottom of the Ocean,† and corals from the superficial strata of the sea, are constantly at work building up geological rocks, like those which were formed by species in former ages, and at the present time constituting parts of the mainland. By their constant work of assimilation, polycistina, globigerinæ, sponges, madrepores, and other workers of the sea, collect the carbonic acid, lime, and silex brought down by the rivers, and rebuild the earth slowly with these materials. Whilst watercourses are gradually wearing away the foundations of mountains and demolishing them particle by particle, the inhabitants of the sea are engaged in laying the foundations of a new world. Some idea may be formed of the immense part played in the history of our planet by marine organisms, when we take into consideration the production of the calcareous formations which cover so large a portion of the earth's surface. Burmeister rightly remarked, that whatever may have been the origin of limestone, dolomite, and chalk, it is quite certain that all the rocks of this mineral composition have been "eaten and digested" by animalcules similar to those met with in the Ocean at the present time. The foraminifera in the bed of the North Atlantic deposit calcareous matter exactly like that found in our present mountains; new oolitic rocks are formed composed entirely of small *orbulina universa*.‡

The best known, if not the most active, of these workers of the sea, these "world-builders,"§ are the zoophytes (*Zoantharia*), number-

* *Recherches d'Ehrenberg en* 1839.—Anton von Etzel, *die Ostsee*, p. 421.
† See above, p. 147.
‡ *Nautical Magazine*, November, 1862.
§ Michelet, *la Mer*.

ing some hundreds of species, the accumulated debris of which forms vast tracts of land in the South Sea and the tropical Atlantic. The corals of more temperate zones do not increase in multitudes sufficiently numerous to form banks of rock to any great extent. Only those waters of which the temperature is at least 66 degrees Fahr., that is, within an equatorial zone about 50 degrees in breadth, form the scene of operation in which these enormous crowds of workmen can live and multiply, and, by the elaboration of the calcareous matter contained in solution in the body of water, can gradually cause dry land to rise up from the bed of the Ocean. The working polyps, most of which belong to the madrepore family, cannot live in any seas which are crossed by cold currents. There is not a single coral reef to be seen all along the western coasts of South America, which, although warmed by a tropical sun, are also washed by the cool waters coming from the south pole. The gradual increase of cold in the deeper strata of the sea is also probably the reason why the coral-builders live only at a slight depth below the surface; below 25 fathoms the dredge does not discover a single specimen.

In certain parts of the South Sea, multitudes of these animated flowers, the different varieties of which shine with the most brilliant colours, give to the surface of the water in its shallower parts the appearance of a field studded with glittering flowers. The colour of the calcareous masses produced by successive generations of madrepores is generally of a dead white. The reefs constructed by the meandrines rise up in conical protuberances, which are covered with winding lines like the circumvolutions of a lobe of the brain; the edifices built by *porites* spread out in large regular strata, while those of other creatures are composed of cavities bristling with points, sometimes even assuming the appearance of petrified brushwood. When the reefs have gradually emerged from the sea, and have been left by the colonies of animals which inhabited them, the different species of coral forming the rocks may often be recognized; but in many cases the stems and branches of coral have been broken into so many fragments, and so intimately mixed up with the debris of shell-fish, that no trace of the original fabric can be discerned; the rocky mass, which is entirely an animal production, appears quite as destitute of debris of any regular form as beds of sand. Every trace of the life which has produced the islands, and is still at work on their outer edges, has completely disappeared. Having undergone this change, the calcareous rock, which, moreover, bears an exact resemblance to strata of the same origin which were

deposited during ancient geological periods, is often very compact, and sometimes even partially crystalline like a sort of marble.*

In reefs still inhabited by living creatures the most active corals, such as the meandrines and porites, are those which occupy the external portions of the rocks which are exposed to all the force of the waves; their calcareous bulwarks, which break the force of the tides and the surf, protect the more delicate species which take shelter in the channels and lagunes inside the reef. The banks are not, however, entirely composed of polyps; shell-fish abound in great variety in all the little pools among the rocks, and augment with their remains the thickness of the mass; echinoderms fill up with their spikes all its crevices; and, lastly, myriads and myriads of foraminifera, forming a lesser world living in this world of corals, swarm in every wave which washes the reef. In many parts of the

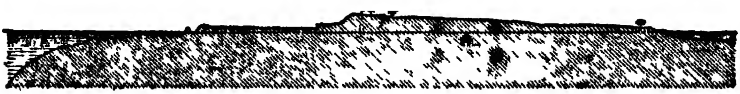


Fig. 175.—Profile of a coral reef, after Darwin

South Seas, especially on the great barrier round Australia, the sand is entirely composed of whitish discs of these marine animals. All this immense swarm of animation, which may be compared to a chemical apparatus of vast dimensions, is incessantly engaged in assimilating the calcareous salts which have been carried away from the earth by the sea-water, and is storing them up for the formation of future continents.

In spots where the subterranean forces, which are at work in the depths of the earth, are upheaving the bed of the seas, the reefs naturally emerge in a period more or less prolonged according to the power which impels them, and, during the course of ages, gradually rise above the sea with the islands of which they have laid the foundations. Nevertheless, the madreporic rocks also ultimately emerge from the water in places where a gentle movement of depression is gradually swallowing up the former land. Many an island which reared its mountain high above the Ocean, has long since disappeared, and ships now cast anchor in the very place where its summit was swallowed up; but round the former sea-coasts, which are at the present time covered by the waves, there is now spread out an annular belt of islets and reefs rising out of the water like a

* Beete Jukes, *School Manual of Geology*, p. 67, ff.

living wall; these extraordinary ranges of narrow reefs, disposed in a circular or oval form in the middle of the sea, constitute those atolls the formation of which has been so well explained by Darwin.* According to Dana the larger coral islands of the Pacific are 290 in number, and together comprehend an area of 60,000 square miles, that is, about an eighth part of the ground rising above the surface of this Ocean. As far as the smaller islands of the same origin are concerned, no attempt has yet been made to count them. The king of the Maldives, a name signifying "*innumerable islands,*" can, without any exaggeration, assume the title of Sultan of 30 atolls and 11,000 islands.†

Since 1702, when Strahan discovered the marvellous productions of the madrepores, every navigator tells us how the structures brought up by the polyps to the level of the water may gradually be

Fig. 176.—Roadstead of Papeiti (Island of Tahiti).

* See in *The Earth* the chapter entitled, *Upheavals and Depressions.*

† Dana, *United States Expedition.*

converted into dry land, and become covered with vegetation. The waves break in pieces the projecting stems, and lifting up the looser fragments of coral, drive them onwards to the highest point of the reef. There, by degrees, they form a bank of debris on which the breakers beat and bring from the open sea sand, broken shells, and the remains of the innumerable organisms which swarm in the ocean. Enriched by these additions brought to them by the waves, the calcareous bank becomes covered here and there with a thin layer of vegetable soil, where sooner or later some seed germinates which has been carried away by the current as it washed the coast of some distant land. A few land plants embellish with their verdure the grey and monotonous coast; after a time trees take root

Fig. 177.—Gambier Island.

there; then insects and worms, carried along on drift-wood as if on rafts, begin to populate the incipient groves; birds resort thither to hide their nests among the foliage; and at last it often happens that some fishing party, attracted from afar by the beauty of the site, come and take possession of the new land, and build their huts on the edge of a spring which has been gradually formed in some cavity by the subterranean filtering of the rain-water. Such has been the history of hundreds and thousands of the islands scattered over the Pacific Ocean and the Indian Sea. Some of them have been known to take their rise during the course of the present century. Thus the island of Bikri, in the atoll of Ebon, had not reached the surface of the water in 1825; but in 1860 it had already become a dry rock with an area of about four roods, and some pandanus sown there by the waves were growing in the sand on the shore. Other islands, formerly separated from each other, are now united so as to form a crescent-shaped tract of land, and the former divisions may still be recognized by their rocks, which are either bare or covered with a scanty vegetation.*

Generally speaking, the section of the ring which is turned towards the point of the compass whence the wind most frequently blows is that which presents the greatest extent of dry ground or even a complete half circle, for the animalculæ building the reef take a delight in the beating of the surf. There are, however, certain archipelagos, like that of the Marshall Isles, where islands continuously increase on the very side of the atoll which is least beaten by the waves.

Fig. 178.—Profile of Gambier Island.

This fact is accounted for by the violence of the north-east trade-wind, which, during six months in the year carries from the eastern to the western reefs all the broken pieces and drifting matter, and thus construct an artificial bank on the least populated side of the atoll.

Still the appearance of reefs differs considerably according to the activity of the coral insects and the various physical conditions of the ground on which they erect their structures. All round a great

* Doane, *American Journal of Science and Arts*, May, 1860.

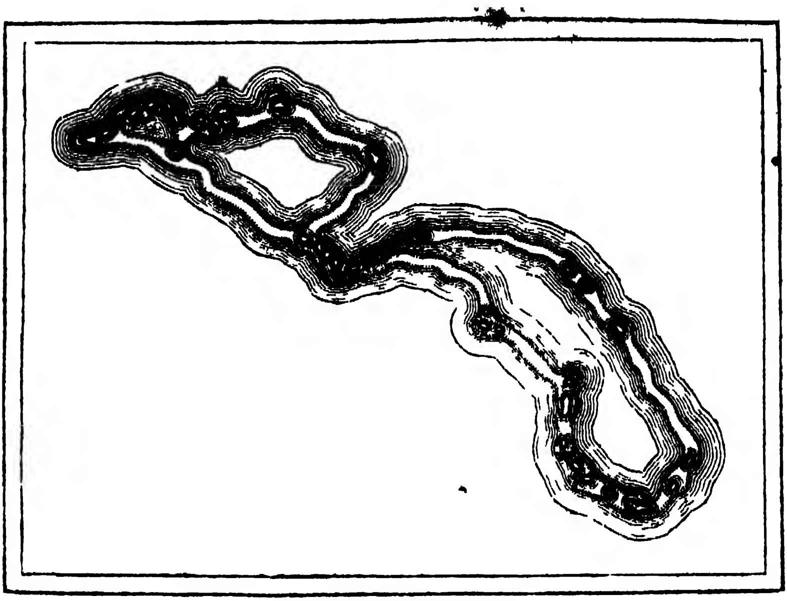


Fig 179 —Atoll of Menchikoff

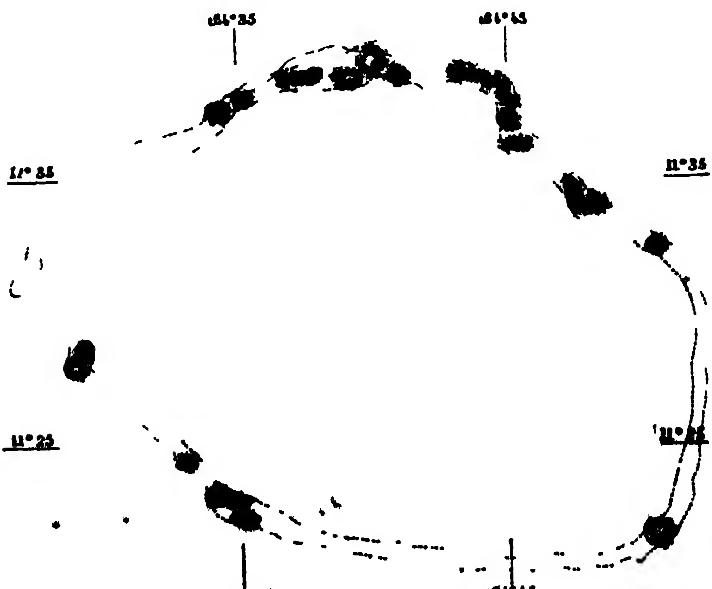


Fig. 180 —Brown s Archipelago.

number of islands,* Tahiti being an example of this class, the reefs of madrepores fringe the shores like the shoals on the rocky coasts of Brittany, and between *terra firma* and the belt of reefs properly so called there is little more than a narrow canal, through which vessels make their way with difficulty; but being protected against the surf of the open sea, they are navigated in safety. Other islands, Gambier † and Vanikaro for instance, are encircled at some little distance by an almost complete belt of rocks of a tolerably regular

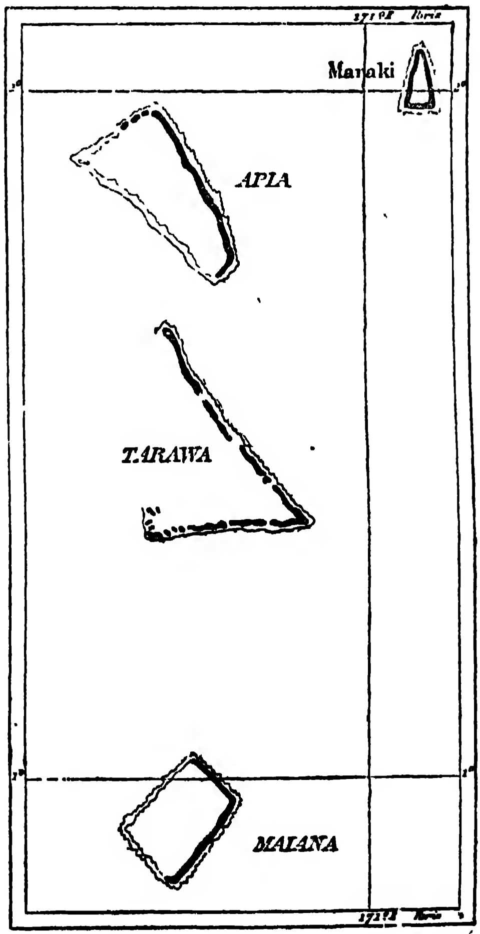


Fig. 181.—Part of the Kingsmill Group, after Dana.

* See the plate on p. 177 † See the plate on p. 178.

formation. In these cases, however, the central isle has disappeared and its place is taken by a lagune which is surrounded on all sides by the atoll with a circle of reefs and breakers. Some atolls are single, like the famous Keeling atoll, which has become celebrated through Darwin's description; others are double, like that of Menchikoff; others again are multiple, innumerable so to speak, like those marvellous agglomerations of the Maldives, where each reef is an atoll in miniature, and, with other reefs of similar shape, constitutes a larger atoll; and this larger atoll is but a link in the immense chain of an atoll having a circumference of 62 miles.* We also find in the sea many groups of scattered islets, which do not seem to differ from the dispersed archipelagos of seas in the temperate zone, and would not be recognized as fragments of some large annular islands, were it not that a circle of shallow water shows that these islets are nothing but the emerged points of a submarine atoll. As an example of this formation we may mention "Brown's Archipelago." Lastly, certain coral islands, especially those in a certain part of the Kingsmill archipelago, assume the shapes of almost perfectly regular triangles and squares. It is difficult to explain this strange arrangement, which doubtless proceeds from the collision of oceanic currents.

By comparing on several occasions the exact height of the coral reefs situated at the foot of the forts on the rocks of the coast of Florida, Agassiz found that the average growth must be computed at from seven to eleven inches in a century. Thus the madrepores appear to take a long time over their work, and very small changes in the comparative distribution of land and sea occupy a long succession of ages in their accomplishment; nevertheless these innumerable multitudes of animals, engaged as they are in the incessant construction of their calcareous edifices, are of the greatest importance in the history of the world. They are at work on almost all the shallows and coasts of the Red Sea, the Pacific, and the Indian Ocean, that is to say, on a total extent of coast-line of several hundreds of thousands of miles. It is not therefore a mere figure of speech when geographers designate corals as the builders up of future continents. Between Australia and New Guinea, in that part of the Ocean which has received the special name of "the Coral Sea," countless myriads of coral insects are employed in concert in no less a work than the reconstruction of that sunken portion of the world which, in the southern hemisphere, once tended to balance the mighty mass of Asia. The continuous line of reefs which stretches outside the

* See in *The Earth* the plate representing the *Atoll-Ari.*

Fig. 182.—The Red Sea and its Coral Reefs.

coasts of Queensland and the peninsula of Cape York is not less than 931 miles in length; towards the entrance of Torres Straits this coral wall, appropriately named the *Great Barrier*, is changed

into a regular dike, the openings of which are known only to the cleverest sailors. For a space of about 310 miles any access to the coast of Australia and the Straits of Torres is completely shut out by this winding rampart of madreporic rocks; and beyond this obstacle ships sailing towards the Sunda Isles have still a number of reefs to round; there is also a complete labyrinth of narrow canals which must be carefully followed ere they reach the open sea. We might justly say that an isthmus of rocks, 124 miles in breath, has always united the Australian continent to the large island of New Guinea.

In the Atlantic Ocean the only coral structures of any importance are to be found at the outlet of the Gulf of Mexico. The peninsula of Florida, a low and marshy tract of country in which the only hills are merely mounds of sand raised by the wind, is entirely composed of coral debris and calcareous sand. This enormous territory, not less than 78,000 square miles in extent, reckoning up to the line where the continental highlands begin, is the work of polyps. Taking for the foundation of their edifices a long strip of sand, which was probably formed between the waters of the Gulf-stream and those of the main sea, the animalculæ, in the first place, built their structures up to the water's edge; the waves have afterwards destroyed all these reefs, and having reduced them to sand, cemented them into one solid

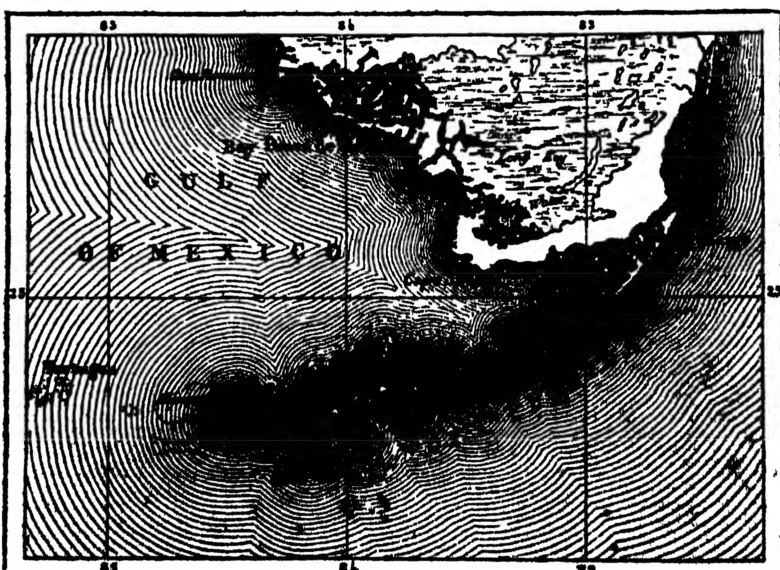
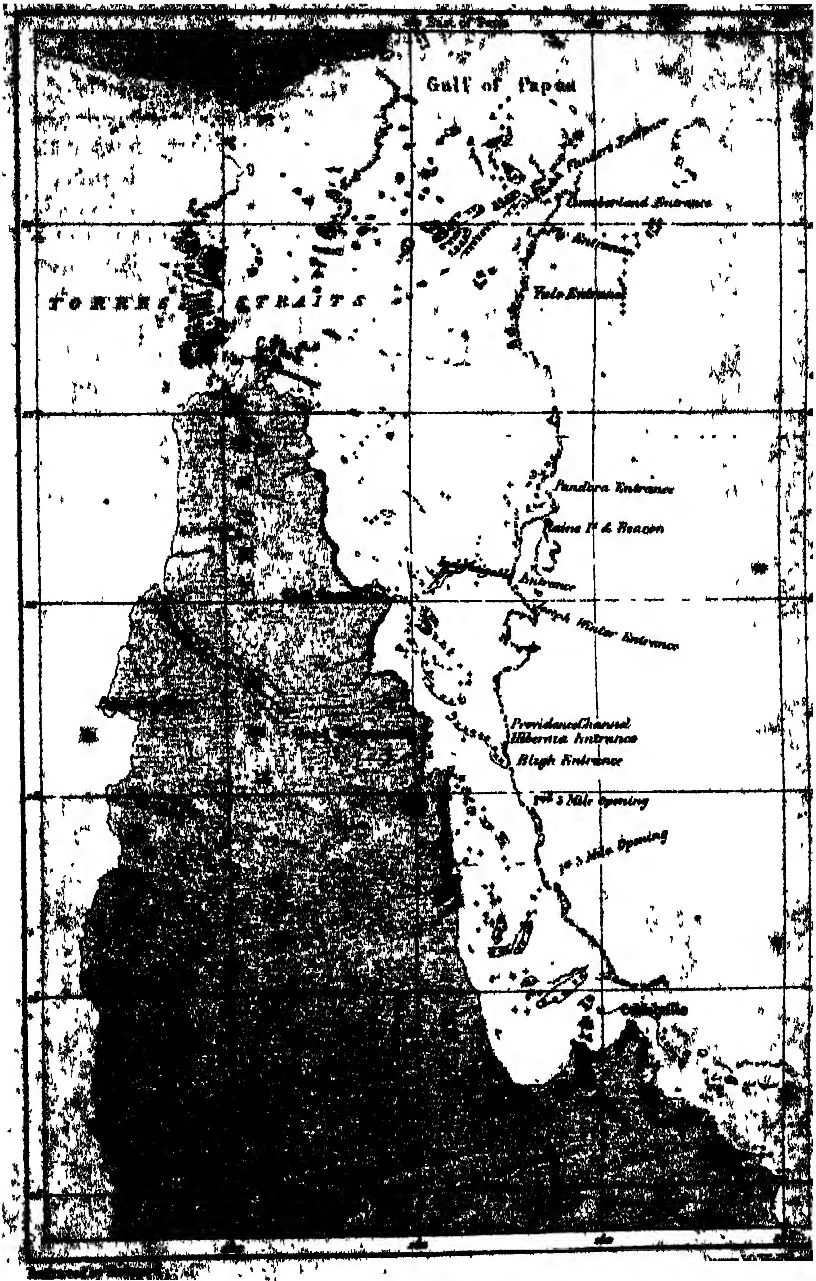


Fig. 122.—The keys of Florida.



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mass in combination with all the debris cast up by the sea.* It must however be confessed that the corals have taken their time over this immense undertaking. According to T. Sterry Hunt, the period which the polyps must have required for raising the reefs of Florida from east to west would be at least 864,000 years, and the development of the peninsula from north to south must necessarily have occupied a period of not less than 5,400,000 years.† Florida has now ceased to increase towards the east; for on this side its shores are bordered by the deep water of the Gulf-stream, and polyps, as they work only in shallow water, cannot live there. The peninsula increases in extent only on its western and southern coasts.

As has been shown by the explorations of Agassiz and several officers of the American navy, the construction of the southern point of Florida presents the remarkable phenomenon of concentric coasts. A long way out, in the sea and even on the very edge of the bed

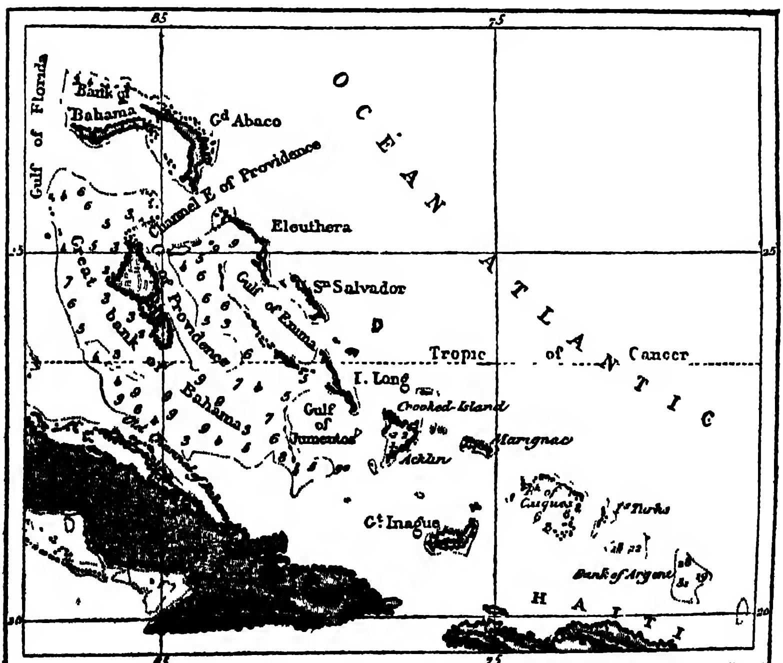

Fig. 184.—The Bahama Archipelago.

* Agassiz, *Coast-survey Report*, 1861.
† Silliman's *American Journal*, March, 1864

which is filled by the waters of the Gulf-stream before they make their way through the Bahama channel, there extends a semi-circular range of rocks, which, here and there, reach the surface of the water, and along almost their whole extent are still in course of construction; this is the future coast of the peninsula. Inside this first range of reefs, which is only indicated by breakers and a few rocks, there extends a long curve of *keys* or *cayos*, composed of islands, islets, and rocks, forming an almost continuous line; this constitutes the true coast of the peninsula, and on its extreme point has been erected, as if to keep watch, the great fort of Key-west, one of the most important military depôts and maritime and commercial stations in the world. Behind this sheltering range of keys, at an average distance

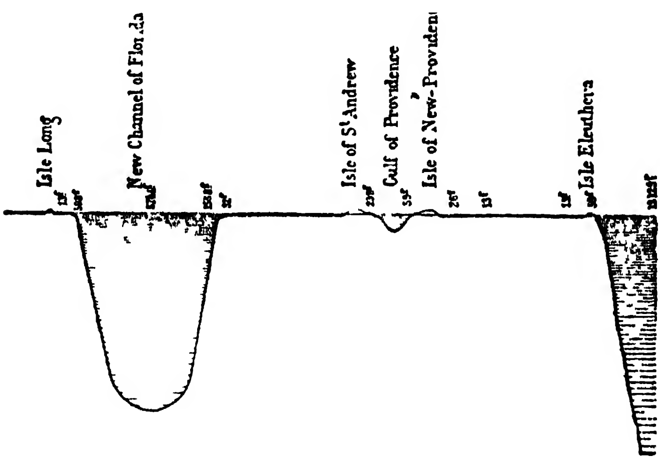

Fig. 185.—Cross-section of the Bahama Islands.

of nine miles, stretches out the regular coast, composed, like the external reefs, of coralline debris; then, further inland, the geologist finds again ancient banks, and separated from each other by marshes and tracts of low lands; these were the reefs which two or three hundred centuries ago were beaten by the waves, at an epoch when the present coast was nothing more than a succession of islets scarcely level with the water.

The Bahama Islands, which are also structures erected by coral insects in the shallow parts of the sea, present, like Florida, a sort of façade which at the east is suddenly cut off by the depths of the open sea; the western side in the still waters of the great banks is

the spot where the organic debris and mud accumulate, which, sooner or later, will form the largest archipelago in the West Indies. On

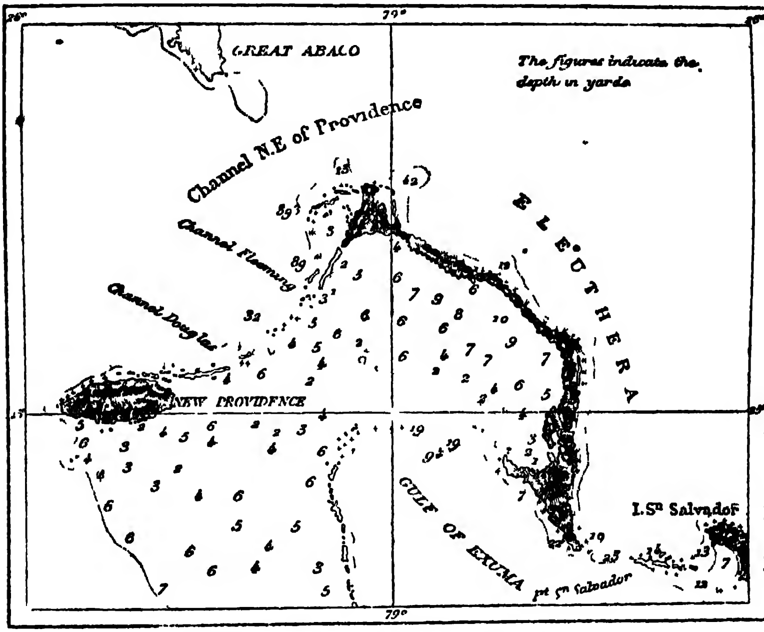

Fig. 186.—The Islands of Eleuthera and New Providence.

the side towards the main sea the islands are developed into a very elongated arc of a circle, and uniformly present the appearance of incomplete atolls; madrepores, astreas, and caryophyllæ, which delight in working when washed by the huge waves of the open sea, cannot, in fact, complete their structures except upon the side which is washed by the surf, and therefore do not build annular walls like those which rise amid the waters of the Pacific.

BOOK III.—EARTH AND MAN.

CHAPTER XIV.

THE INFLUENCE OF NATURE ON THE DESTINY OF MANKIND.—ANTIQUITY OF THE HUMAN RACE ON THE EARTH.—MONOGENISTS AND POLYGENISTS.—FUSION OF HUMAN RACES.

MAN does not only live upon the surface of the soil,—he has also sprung from it; he is its son, as we learn from the mythologies of all the nations. We are of the dust, the water, and organized air, and whether we may have sprung from the slime of the Nile, whether we may have been formed from the red earth of the Euphrates or the sacred alluvium of the Ganges, we are none the less the children of the "beneficent mother," like the trees of the forest and the reeds of the rivers. She it is from whom we derive our substance; she nourishes us with her mother's-milk, she furnishes air to our lungs, and, in fact, supplies us with that wherein "we live, move, and have our being." It must therefore necessarily be the case, that those special forms of the earth, with which their flora and fauna harmonize so wonderfully, should be likewise reflected in the vital phenomena of that one fauna which we call mankind.

All the organisms which exist on the surface of the earth may, it is true, act in opposition to nature and infringe the limit fixed by the various climates they have been used to according to the intensity of their vital energy. Plants and animals are ever seeking to enlarge their domain, and, species by species, carry on an incessant struggle for the possession of the soil. Owing to their vital energy, the more energetic tribes shift their possession and become diffused over vast countries where the geological and climatic conditions are exceedingly varied; but as they pass the boundaries of their native habitat, the types die away or become modified under the influence of the new surroundings. The harmony between the earth and its products is

thus disturbed, but only to be gradually re-established, in conformity with the laws which govern all planetary phenomena. But in thus exercising their own peculiar energy so far as is consistent with the conditions of their life, the special faunas and floras only add to the wonderful harmony of the earth and of all that springs up and grows upon its surface.

Man, the "reasonable being" who so much delights in boasting of his free will, is nevertheless unable to render himself independent of the climates and physical conditions of the country which he inhabits. Our liberty, in our relations with the land we live in, consists in recognizing its laws in order that we may live in accordance with them. However great may be the comparative facility of life and action which we have gained for ourselves by our intelligence and personal volition, we none the less remain mere products of the planet; fixed to its surface like imperceptible animalculæ, we are carried along by all its movements, and are dependent on all its laws. Moreover, we do not belong to the earth merely as isolated individuals, for associations of men, taken as a whole, must at their origin have necessarily been moulded into shape on the earth on which they took their rise; in their inner organization they have been compelled to reflect the innumerable phenomena of the continental outline, their rivers and sea-coasts, and their circumjacent atmosphere. All the primitive facts of history are explained by the disposition of the geographical theatre on which they have taken place; we have even a right to assert that the history of the development of mankind has been written beforehand in sublime lettering on the plains, valleys, and coasts of our continents.

A geometrical parallelism is not, however, the point in question here. The resemblance between facts and the scenes that surround them is not an absolute one as would be the image of an object reflected in a looking-glass. No, the accordance which exists between the globe and its inhabitants is composed both of analogies and contrasts; like all the harmonies to be perceived in organized bodies, it proceeds from conflict as much as from concord, and never ceases to oscillate round a shifting centre of gravity. The forces at work both on the surface and in the heart of the earth are always in action, and geological phenomena bear witness to this fact; in the same way, man is incessantly engaged in a conflict with the globe on which he dwells; having submitted to be a child of nature during the ages of primitive barbarism, he has gradually emancipated himself, and now endeavouring to adapt to his use the forces of the earth,

he has, so to speak, made them his own. The action of the planet on man and the reaction of man on the planet are the agencies which have given rise to that harmony which forms the history of the human race. These facts, however, have become little more than truisms since the Humboldts, the Ritters, and the Guyots have by their labours established the solidarity which exists between man and the earth. When the illustrious author of the *Erdkunde* compiled, by his unassisted efforts, his great encyclopædia, the grandest geographic monument of ages, the leading idea which inspired him was that the earth is the body of mankind, and man is the soul of the earth. Without thus proudly appropriating to ourselves the globe on which we tread, we are still justified in asserting that though for a long time we were nothing more than its unconscious products, we have become increasingly active agents in its history

It is now proved that man has existed on the earth since a very remote period. Written documents do not carry us back further than thirty or forty centuries; the most ancient remains of edifices built at any previous epoch, which also may be called archives of stone, date back perhaps two thousand years before; but far beyond this short historic period, which scarcely comprises the lapse of one hundred and fifty generations, extends a space of time, certainly much longer, known to us only by pure tradition. Then mankind, rising to a more enlarged self-consciousness, linked age to age by legends, poems, and symbolic formula; the reminiscences of great events, migrations, wars of races, alliances, exterminations, and triumphs of industry, were incorporated into religion itself, and, in an increasingly varied form, were handed down from age to age as the heritage of nations. In still more ancient times, in the dim mist of bygone ages, our ancestors lived the life of wild beasts in forests and caves. Tradition, no less than history, is dumb as to this epoch of the human race; but the strata of the earth, explored in our time by geologists, are beginning to reveal to us both the existence and the customs of these ancestors of ours long unknown to us.

To say nothing of the objects discovered at various epochs, at a time when science, still timid, refused to recognize the antiquity of man, so many human remains, and so many productions of primitive industry have been lately met with, that, comparatively speaking, there can no longer be any doubt as to the long duration of our species. Not only did our ancestors inhabit forests contemporaneously with the *Bos urus*, now banished into the Caucasus, and in Europe represented in a few parks by one or two specimens; but anterior to this epoch

they also existed during the Glacial period, at a time when France and Germany presented the aspect now offered by Scandinavia, and the reindeer, now banished to the vicinity of the northern zone, frequented the glaciers of the Alps and the Pyrenees. At a still more ancient period, at an epoch when the European climate, which must subsequently have become so much cooler, was on the contrary much warmer than in the present time, the cave-men had for their contemporaries certain species of rhinoceros and elephants which are now extinct, and even then artists, humble predecessors of Phidias and Raphael, endeavoured to carve representations of mammoths upon their implements which have been preserved in the earth of caves. Before this epoch man still existed, striving for mastery against a formidable enemy, the great cave-bear, representations of which he likewise left engraved on stone; and still further back, in the dim mist of ages, we learn from other remains, those of the *Elephas antiquus* and *meridionalis*, that our ancestors were already in being during a period whose life was once believed to have been separated from the present era by a succession of sudden cataclysms. How many thousands or even millions of years have elapsed since that time? This question as yet no one can answer.*

The shape of the skull shows that the human remains found at Eyzies near the border of Dordogne, must have belonged to a race which even now might be reckoned among the most beautiful of its kind; the skulls found by M. Garrigou in the caves of Ariége, and perhaps belonging to people of the historic epoch, are of very noble proportions; but the skulls found at Engis in Belgium, Neanderthal in Rhenish Prussia, Borreby in Denmark, and Eguisheim in Alsace, prove that numbers of the primitive inhabitants of western Europe were very much inferior to the civilized people of our days. Though perhaps more agile in pursuing their prey and more powerful in bringing it to the ground, these representatives of extinct races were less intelligent and had less of the man about them than we, and their facial angle bore some approach to that of the wild beasts with which they were compelled to struggle for very existence. As Professor Huxley remarks, the difference in capacity between the skull of civilized man and that of the man of Neanderthal or Borreby, much exceeds the difference which exists between ancient human skulls and those of the largest-sized monkeys. Must we therefore conclude, with Carl Vogt and many other anthropologists, that man is descended from one or several species of these quadrumania, which

* Boucher de Perthes, Lartet, Christie, Lyell, Lubbock, Garrigou, Broca, &c.

have gradually developed by the process of selection or through a contest for life extending throughout a long lapse of ages? We have here a theory which, far from being humiliating to mankind, should on the contrary be a source of pride; our own immense progress would justify a very considerable expectation on this point. Nevertheless, although it is all very well to set up and discuss these grave hypotheses, we must however be on our guard against accepting them as demonstrated facts as long as no direct evidence has been definitely brought forward.

Since we are necessarily still in doubt as to the very origin of mankind, it is obviously impossible to ascertain whether the different races of the earth are descended from one couple or from several primitive groups. Is it a fact that all men, black and white, red and copper-coloured, own the same Adam as their progenitor, and the same Eve as their common mother? Or has each continent, each isolated tract of land, produced autochthonous races distinct from every other, as it had previously produced its peculiar flora and fauna? Although this question is as yet insoluble, none is more discussed by anthropologists. Some maintain that the primitive unity of the race is an indisputable fact, and that it could not be denied without making a kind of attack against the majesty of mankind; others are of opinion that there were three, four, five, ten, or eleven primitive groups; there are some also who talk of hundreds of various races which have sprung up here and there at different epochs on continents and islands, like the plants, the seeds of which were sown, so to speak, at random. In support of this theory they cite the well-known fact that the types of fossil man in western Europe present contrasts much more striking than those observed in the races of our time.

Moreover, the passions of our nature, having no alliance with science, have been mixed up in this debate. At the time when the American Republic was still unfortunate enough to reckon along with its thirty millions of white men, the freest in the universe, four millions of negroes condemned to the most degrading slavery, both polygenists and monogenists used to dispute *à outrance* in scientific language; they went so far as to invent arguments, not to establish the truth, but either to justify or to curse slavery. Even among those who believed in the tradition of the primitive unity of the human race, many asserted, out of hatred to the blacks, that this unity has been broken during the course of ages, and that the children of slavery were for ever doomed to the lash and to the iron collar.

These contests, provoked by the strife of interest and feelings, have not resulted in any scientific certainty, and the origin of our race remains as obscure as ever. This ignorance is naively illustrated by most of the myths which recount how the life of the first men began by sleep. "Nothing was in being," say the old men of an Indian tribe, "all was null and void; there was no sky, no earth, no sea, no shore. Suddenly seven warriors found themselves seated on the edge of a lake smoking the calumet of peace, and their wives were already working in the wigwams." No legend brings more vividly before us that man passed his infancy as if in a dream; his first commencement was living without knowing it.

It matters moreover but little whether man is descended from one or several primitive couples of ancestors; it is of little importance whether races so diverse in their nature were all begotten by the same family, or whether they were born in different countries and at different epochs, provided that this unity, though doubtful in the past, becomes a matter of certainty in the future? This is one of those great questions which anthropologists are now putting to themselves, and we believe that it will be very near its solution when the results shown by experience are adhered to in good faith. According to some savants, various races cannot blend one with the other; the black cannot permanently unite with the white man; the Redskin, the South Sea islander, the Arab, and even the Chinese, can never enter the great family of their brother nations; and more than this, the Hindoo, although no less Aryan in his origin than the western European, and actually his precursor in arts and sciences, is compelled to remain excluded from the circle of the proud Celtic and Germanic races without renewing the former bonds of parentage. According to this theory, which is absolutely enunciated by some and more or less softened down by others, the progeny of any union between different races would be a family of hybrids destined either to die away from sterility, or to produce successive generations the special type of which, growing weaker and weaker, could only ultimately result in the reproduction of one of the two original races. And even a more melancholy fact! Certain inferior tribes, altogether incapable of uniting with the masters of the earth or even of living in the same civilized state, will have no alternative left but to die out; the earth not being large enough for them and for the men of the victorious race!

Alas! the self-styled civilized man has often proved his superiority over other races by a merciless course of destruction; he has hunted

them down like game, sometimes in order to seize their land, their jewels, or their arms, sometimes to make slaves of them, and sometimes merely for tasting the pleasures of wholesale slaughter. The number of victims which have been thus sacrificed during the last four centuries must be computed by millions and millions, and whole tribes, and even nations, have completely disappeared. It may be easily understood that in the face of this immense massacre the fusion of races could not be effected. Nevertheless, if the greater part of Europeans, instead of showing themselves to be mere exterminators and clearing away all before them, had been somewhat less of barbarians, if they had adhered to the plan of evincing their native generosity by coming forward as friends and as benevolent and just individuals, can we believe that they would have failed in coming to a good understanding with the natives, and that an union would not have been easy between the distinct races? In every part of the world, the common understanding of what is just and right would have marvellously facilitated the alliance. If it is a fact that fusions between different races can produce nothing more than sterile hybrids, the case is plain, mankind is condemned to death, and to a rapid death, for peoples and races are every day more and more mixed up, the frontiers of countries are disappearing, and by cross-breeding upon cross-breeding all men will ultimately become one and the same family.

In spite of the terrible conflicts which have taken place, in spite of exterminations, and in spite of slavery, the whole of South America, the republics of Central America, the West Indies, and a portion of the United States, are now peopled with a mixed race in which blacks, whites, and red-skins are found blended together. Is not that part of the earth which we call the New World, inhabited by newly-formed peoples, the type of which is in no way confused with that of either of the races which produced it, but is all its own? Is it not a fact that all these populations, which resemble the European in intelligence and ideas, the Indian in an indomitable spirit of stubbornness, and the African in his enthusiasm and gentle qualities, are living proofs that the various human races might easily be united into one in spite of the difference in their origin. Subjected to the influences of rapid changes, journeys without end, the various elements brought in by emigration, the intermixtures between families, the modification of climates produced by cultivation,—the types of mankind, becoming more and more mobile, blend and ultimately unite: if these types in former days remained unchanged, the cause was the immobility of nations. The

Egyptian of our time, although characterized by slight modifications pointed out by Brugsch, is much the same as the figures which we see enslaved and bent down on the fronts of obelisks and on the pedestals of statues. But there is no painting, there is no design engraved either on stone or metal, which has ever given us any indication of the type of the modern North American, or *Yankee*, or of the Spanish-American.

CHAPTER XV.

INFLUENCE OF CLIMATE.—TROPICAL ZONE —FRIGID ZONE.—TEMPERATE ZONE.

THE various conditions and surroundings regulating climate are so extremely diverse in different parts of the world, it is only possible in the most general way to point out their influence on the inhabitants. Thus in the tropical zone there is a complete contrast between deserts destitute of water and verdure, and the luxuriant lands on which at one time the sun shoots forth its flame-like rays, and at another the clouds pour down their showers in cataracts.

The development of life is rapid in climates where the winter season follows immediately upon tropical heat; it advances with rapid strides, and death also hastens on behind it; gigantic trees inhale currents of carbonic acid through their thirsty leaves, and absorb them into their numerous tissues; bamboos may almost be seen to grow, and marshes are concealed under isles of floating herbage. No sooner does a storm overthrow the mighty giants of the forest than fresh vegetation springs forth from the shattered bark. Thus life, ever indefatigable, causes multitudes of new organisms to shoot out from the death of the old. In this fruitful climate, where the air is pervaded with heat and saturated with moisture, those vegetables which are used for the food of man grow in the greatest abundance. In many regions of the tropical zone all that man has to do when in search of food is to shake the branches of the trees or pull up roots from the ground. His needs are so very few and life is so easy to him, that he cares little about it; he is not compelled to sustain it by dint of work, but it meets him as it were half way, and he almost despises it, because its favours are so generously offered. He therefore meets death without a regret, and not one tear is shed when he closes his eyes for ever. Sudden epidemics visit the inhabitants, as storm-clouds beat upon a forest; sometimes even famine carries away whole populations, who have not been wise enough to store up the resources offered to them by nature against future times of want. But what matters the death of a man or even that of whole tribes? Children innumerable take the place of those

who have departed, and grow up like the grass in a newly mown meadow. Thus the mildness of the climate, the fertility of the soil, the exuberance of life, and the suddenness of death, take an equal part in maintaining man in his native carelessness and idleness. Taken as a religious being, all he can do is to bend in silence before the majesty of mighty nature. Her violence is too terrible, her energies are too impetuous, the great alternations of her actions are too regular, for the feeble being placed in her midst to be anything but her slave. He will worship her in all her phenomena: in the rays of the sun, because they burn and destroy; in the clouds, because they peal forth thunders; in the dark forest, because serpents and tigers are hidden in its depths; in all that surrounds him, because everything lives with an irresistible force of life which may at any time cause his death. The stupendous work which is unceasingly going on around him hinders any personal labour; he thinks but little; when, like the Hindoo, he meditates and contemplates the laws of nature, his ideas somewhat tend to the profound and the immutable, like the laws of which they are the reflection.

The rich nature of the tropics even on account of that richness is, as we see, not the most favourable to the progress of mankind, but the frigid zone is still less fitted to be the residence of prosperous nations. But a few tribes have wandered into the solitudes of these countries, where they have struggled painfully with the climate in order to extort from it each day enough to keep up a miserable existence. As, on account of glaciers and the absence of vegetation, they cannot penetrate far into the interior of the islands and continents on which they live, they build their wood or snow huts on the sea-shore. There, at least, the wind now and then wafts to them a few gusts of equatorial air, there the counter-currents drive upon the shore water which has come from the tropics, and still retains something of its primitive warmth; and when the sea is not too stormy, or too much covered with drifting ice-bergs, the fisherman is able to venture out in his leathern boat in quest of seals and fish. When he has pierced with his harpoon the animals which are to serve as food for his family, he returns to the small black hole which forms his miserable retreat, where, warming himself by the flame of a lamp, he spends the long winter night, which seems as if it would never end, for even the sun, the source of heat for all terrestrial life, abandons the frigid zone for whole weeks and months, while the aurora, which at intervals takes its place, sheds but a livid gleam, a mere phantom of the day. Existence is a difficult matter during this

long and gloomy winter; famine, too, often makes great havoc among these people, and sometimes whole tribes have disappeared without leaving a trace behind them. How could it be otherwise than that the mind of the Greenlander, the Esquimaux, and the Kamtchadale should suffer under the influence of the desolate climate of the polar regions? All travellers relate that the most simple pleasures are sufficient to fill up the cup of joy for artless beings like these whose life is always so monotonous; in their struggle for existence ambition does not form a part, for the main point with them is to procure food, and the soil is too ill adapted for cultivation, and the climate is too inclement, for them to be able to counteract the difficulties presented by the land, and to make any endeavour to appropriate it for their own use. They are loving and gentle in disposition, for a family living together as they do in their snow hut must be all the world to each other; they are attached to their native land and die when obliged to leave it, because their ideas are as unsophisticated as the country in which they were born, and there only can they experience the simple pleasures and peaceful joys which refresh them after their labours. Even among nations there are some that are always children, and they perish when they are torn away from their mother's breast.

The two temperate zones, and particularly that in the Northern hemisphere, are the portions of the planetary surface which have been the most favoured in the development of the human race, and when the more or less civilized nations of Western Europe and North America proudly attribute to their inherent virtues the great progress attained by them, they little know how much is owing to the favourable climate which has assisted their efforts.

The distinctive characteristic of the temperate zone is the equal and periodical alternation of the hot and cold seasons. In the tropics, the mean temperature varies but slightly, and in the frigid zone, intense cold yields to a milder climate for only a few weeks during a very short summer; but in the tract of land included between the two extreme zones, heat and cold follow each other regularly, so as to form two well-defined seasons following the path of the sun on the ecliptic. The nations of the temperate zones are reared in a powerful climatic tide, the flow of which rises from the equator towards the poles during spring and summer, the ebb descending from the poles towards the equator during the autumn and winter. The extremes of temperature are always separated by long intervals of weeks and months, and the influence of contrary

climates is only shown by successive gradations. In the temperate zone nature wears alternately a joyful and a melancholy aspect; during the warm season the earth is gay with smiles, covered with flowers and foliage, it fills the air with its perfume, and abundantly absorbs the rays of heat, light, and life, which the sun sends down to it; in winter time nearly all that is green seems to have faded, the delicate outline of the bare branches on the trees stands out in relief against the sky, and the ground is often covered with snow as if to shield it from the outer air, and in silence and retirement to prepare for the germs of life which will bud forth in the spring.

This succession of seasons does not, however, take place so abruptly as to bring about any injury to the organism of man. Months, weeks, and days follow their course in the circle of the year with a harmonious and measured step, and man, borne along by the seasons, must involuntarily be carried along by their movement; during the course of a year he passes through climates of the most various nature, and, gazing on a landscape which is ever changing, he alternately sees nature like that in the tropics and that in the poles fluctuating around him. The scenes which follow one another season after season represent both to his body and mind journeys of many hundreds of miles; he is, so to speak, constantly changing his habitat on the surface of the globe. Nature is exhibited to him in all the beauty she wears in every climate without presenting to him, except but rarely, the fearful aspect she presents in the zone of hurricanes and that of boundless snows.

The variety of climatic phenomena, and the quiet way in which they follow one another, have made the temperate zone the best climate for the human race. The life of man is developed better than anywhere else in these regions, where the action of nature is produced energetically and regularly, and the forces proceeding from the equator and those proceeding from the poles mingle with each other, increasing by their combination the number of their phenomena, and yet, notwithstanding, mutually diminishing the violence of their action. In consequence of the regular oscillation of their zone of contact, these forces bring about at the same time a condition of movement and equilibrium; man, to whom they have given the breath of life, may, by contemplating their alternations, perceive the immutable eternity of the laws which guide them, and the ever-varying appearance of the facts which spring from them. A still more important fact is that man is constantly incited to labour, for notwithstanding the beneficence of nature in these temperate re-

gions, it is only shown in moderation, and to those who study and understand her. In the spring, the ground must be cultivated in

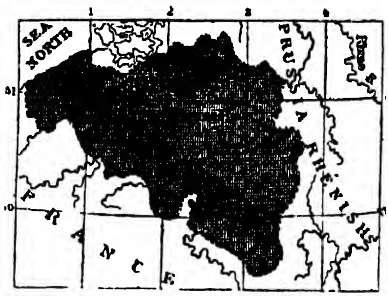

Fig 187.—Density of the population in Belgium.

prospect of winter, and each season must be made a preparation for that which follows. Confident in the bounty of the earth, the la-

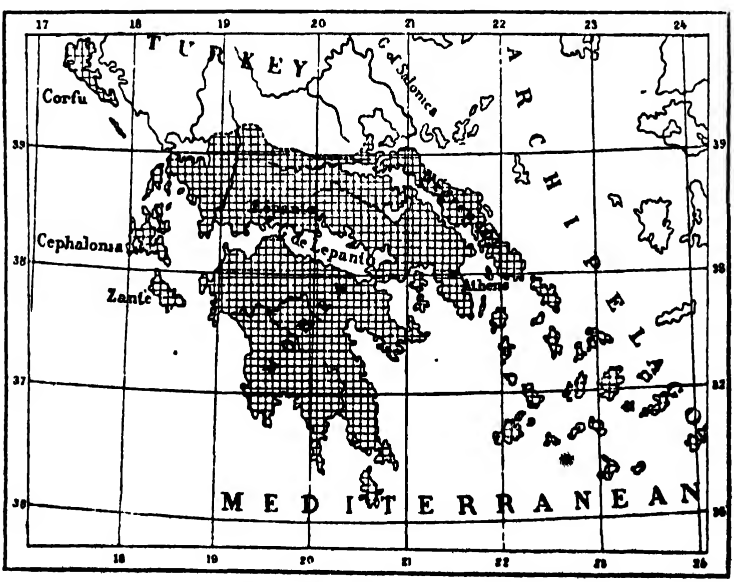

Fig. 188.—Density of the population in Greece.

bourer learns to deprive himself of a part of the grain which forms his very existence, knowing that some day he will gather a harvest

from it; by incessant and successful efforts he acquires shrewdness, knowledge, cheerfulness, and love of life.

Therefore, in all the countries of the temperate zone which are blessed with a fertile, well-watered, healthy soil, and are provided with easy channels of communication, there has always been a numerous and increasing population, in spite of the wars, massacres, and invasions to which rival ambition has so often given rise. As far as Asia is concerned, the central part of the temperate region is the locality where we find that "rich central flower" which by itself comprehends more than a quarter of the human race; at the other extremity of the Old World, it is also towards the middle of the same zone, in Belgium, England, and northern France, that we find swarms of men living in the closest proximity to one another. Belgium is the country which has the largest population as compared to the whole world, and contains more than one inhabitant to each acre, or at least a quantity twenty times greater than the rest of the continent. Greece, which is one of the least populous countries of temperate Europe, is, however, in proportion three times more thickly populated than the whole of the dry land of the earth taken as a whole; the comparative populations of the two countries may be imagined from the two preceding maps, in which, according to a somewhat different system to that of M. Minard, the density of the inhabitants, for an equal surface, is made proportional to the number of squares. The space of 2050 miles in width comprehended between the 25th and 26th degree north latitude, which is not even a third of the continental surface, contains two-thirds of the population of the globe, and this is the tract of country where, in our time, the number of inhabitants is still increasing with the greatest rapidity.

CHAPTER XVI.

INFLUENCE OF THE RAISED OUTLINE OF THE EARTH ON MANKIND.—TABLE-LANDS, MOUNTAINS, HILLS, AND PLAINS.

THROUGHOUT the globe the inequalities in level of the various continents have a singular influence upon climate, and, consequently also, modify in the most varied manner the destinies of nations. Instead of following one another regularly from the equator to the poles according to the lines of latitude, the zones of temperature intersect and rise one above another; the surrounding conditions here and there are abruptly varied, and with these conditions the populations also vary.

Taking the mighty fabric of continents, there are some table-lands which are of the greatest importance in the history of mankind. Rising up in the midst of plains, with a system of mountains, rivers, and lakes peculiar to themselves, with a flora and fauna belonging exclusively to them, and a particular climate, always colder, and generally much drier, than that of the lower lands, table-lands offer the most difficult barrier to the migration of nations; for the wide seas, formerly quite impassable, are now easily crossed by ships, and nations of the same origin settle on opposite shores, and become more and more united by voyages and commerce. Table-lands in cold or even temperate regions are not merely boundaries between nations; numbers of them are, indeed, nothing but deserts on account of the dryness of the soil, the rigour of the weather, the violence of the winds, and the snow-storms. In South America, travellers can never venture without danger on the table-lands of the Andes between Chili and the Argentine Republic; even in France the almost uninhabited *causses* of Lévezon, Cavalerie, and Sévérac are very dangerous to cross in winter-time, and not unfrequently carriages are left there buried in the snow. Most of the table-lands of the torrid zone are equally desert, owing to the dryness of the air and the soil, and also on account of the thick saline beds with which the ground is covered; but by a remarkable contrast, there are also certain table-lands which, in the region of in-

tense heat, are the most favourably situated countries for the progress of man. Like rich hanging gardens, rising to a height of 3000, 6000, or 8000 feet in the air, these table-lands bear on their marble or granite pillars a fragment as it were of the temperate zone, with its climate, its products, and its comparatively prosperous people. Thus, the table-land of Ethiopia, peopled by a race distinguished from all others in Africa for its intellect, dignity, bravery, attainments, and progress, rises like an enormous citadel between the deserts of the west, the marshy valleys of the north and south, and the burning shores of the Red Sea. In the same way in America the great Peruvian table-land once inhabited by the Incas, the high lands of Granada, where the Muyscas and other Indian nations live, and the table-lands of Guatemala, Yucatan, and Anahuac, are almost the only parts of the New World where original civilization has spontaneously developed itself, flowers which could not grow in any other soil, yet brutally torn up by the conquering Spaniard.

Thus, it is according to the latitude, the rainfall, and the arrangement of the surrounding country, that table-lands have a favourable or unfavourable effect on the destinies of mankind; on the one hand, as in the whole of central Asia especially, there are thinly-scattered and often nomadic populations, in quest of springs and streams of water and fertile meadows, and very frequently also engaged in expeditions of murder and pillage; on the other hand, as in tropical America, there are comparatively peaceable nations, busied in agriculture, manufactures, and commerce, and gradually developing their autochthonous civilization. Mountains also exercise very different influences on the inhabitants of their valleys, according to the altitude of the lands inhabited, their temperature, and other climatic conditions, the nature of the rocks, the aspect of the slopes, and the abundance of light. How great, in this respect, is the contrast between the Italian valleys of the central Alps and the French valleys of the mountains of Dauphiné! The former are steeped in sunshine, bathed by the blue waters of the great lakes, and open widely on to the verdant plains of Lombardy; from the summit of the headlands, the villagers survey an immense horizon, exhibiting, as if in a perfect picture, the most charming varieties both of land and cultivation. On the contrary, in the dreary district of Valgodemar, in the gloomy valleys of Dévolny, the mountaineer sees nothing around him but crumbling rocks, barren steeps, and scanty crops of barley or potatoes produced, as it were unwillingly, by the stony soil. During part of the winter the sun, which is hidden by the

high mountains rising to the south of Valgodemar, describes its daily course without the inhabitants of the valley seeing anything but its pale reflection on the distant summits; and when it appears again in the happy days of spring they greet it as a divinity. The village of Andrieux, built as it is in a basin of the valley, remains for a hundred days hidden in the shade in the midst of the pale white snow; therefore, who can express the joy which is felt when the imprisoned inhabitants, on the look-out for the first ray, see it dart like a luminous arrow above the crest of the forbidding mountains! In the valleys of the Alps the shivering inhabitants have built nearly all their farm-houses on those slopes of the pasture-lands which are the best lighted by the sun. (See Fig. 190)

Fig 189 —Valgodemar

Some no less striking contrasts among the inhabitants themselves correspond to the great diversities presented by the outline and trend of the mountains. The finest race of men are found living in the high valleys and on the sides of the Caucasus; most of the inhabitants of the Alps are also remarkable for strength and health, and yet, notwithstanding this fact, Switzerland is the country which, in proportion to its size as compared to the whole of Europe, has the largest number of cripples and other infirm persons. *Crétins* may there be counted by thousands, just as in Savoy, the Pyrenees, and nearly all mountainous countries. Whatever may be the special cause or the various circumstances which predispose to *crétinism*

and to the infirmities caused by goitre, whether it be the want of aëration in the streams, the absence of iodine in the water which is drunk, or the rarity of the sun's appearance, still it is a fact that idiots and persons affected with goitre are to be met with much oftener in gloomy mountain-valleys than in open plains lighted by the sun, open to all winds, and watered by broad rivers. Even lately, many a village of Savoy, such as Bozel or Villard-Goîtreux, had more than a third of the number of its inhabitants composed of idiots with deformed necks. According to Caldas, a tenth part of the population of New Granada living in the narrow space between the wooded steeps of the high summits and the shores of the Magdalena and Cauca and their tributaries, are placed by the sad malady of *crétinisme* outside the very pale of conscious humanity. Thus the most picturesque countries are sometimes inhabited by men in the most degraded state of existence.

Fig. 190.—Valley of the Plessur.

Notwithstanding all the varieties exhibited in mountain-nations, it may be asserted in a general way that they are distinguished for courage and firmness. Their broad chest, containing lungs with more ample and numerous cellules than the lungs possessed by the inhabitant of plains, is filled with both a purer and a lighter air;* their eyes, well accustomed to look down from some elevated cliff into the depth of the valleys, and to discern afar off animals cower-

* Alcide d'Orbigny, *Journey in South America*, vol. iv., p. 124.

ing in the hollows of the rocks, are bold, and glitter with a piercing lustre; their features are expressive, and their head nobly set on their shoulders; with an even and quiet gait and a firm step they climb the steepest rocks and bound over the glaciers in pursuit of the chamois. Their daily toil is most laborious, and nothing but a courage and perseverance proof against every trial, enables them to obtain the food necessary for their support. In many spots the ground is so steep that it is impossible to make use of animals in cultivating it; there are some mountaineers who plough the furrows with their own hands, and lay down manure to cover over the seed; sometimes, even, they are obliged to carry on their shoulders the fertile mould brought down into the low grounds by torrents and avalanches. In winter they are besieged by snow, and blocked up in their houses so that frequently they are unable to go from village to village without peril of their lives. It is not, therefore, surprising that at the first approach of cold weather they begin to think of leaving their homes and descending towards the plains, which they speak of admiringly as "level as floors." From every valley of the mountains of Auvergne, the Pyrenees, the Alps, the Apennines, the Caucasus, and the Atlas, troops of mountaineers come down each year; some work for the agriculturists of the lower lands; others follow some trade learned during the interminable leisure of past winters. Actuated by love for their far-distant family, no business comes amiss to them; they deny themselves every pleasure, and, greedily economizing the smallest gains, constantly labour to increase them. No genius is so full of resource as theirs, and by a sort of tacit agreement they have, throughout all Europe, distributed work among themselves, mutually sharing in the various itinerant trades. Among them, the pedlars each have their own peculiar line of business. There are some, like those of Venosc in Oisans, who visit the large towns with rare plants from their pastures or minerals from their rocks; others sell tools, engravings, or coarse stuffs; and, lastly, there are some who, as thousands of Swiss recently were in the habit of doing before it was thought a scandal to their country, gave themselves up to the vile trade of becoming a soldier in the service of either enemy or friend.

Nevertheless, although at the first approach of cold the mountaineers emigrate in troops, it is almost always with the intention of returning, like the swallows and storks. Villages which are nearly deserted during the snowy months, are peopled again in the spring, and the petty tradesman of the plains sets himself courageously to

the hard work of cultivating the barren soil which covers the rocks. The high summits are too beautiful and too vividly impressed on his mind for him not to love them involuntarily as it were, and when far away from them he is always longing to see them again. In level countries, which he admires so much on account of the evenness of the ground, he looks back with affection to the sloping and rocky fields of his native land, the narrow meadows perched on the edge of precipices, the white snow heaped up on the beds of rock, and the bright summits, which in the morning reflect the first gleam of dawn and in the evening are lit up by the last ray of the setting sun. The inhabitant of level plateaux meets in his migrations with a nature like that in which he has lived all his childhood, and delights in roaming over unlimited space, without even thinking of the steppes where he was born; but the mountaineer can never forget his native valley which is all in all to him, and if he leaves it for ever he must be forced by the direst necessity. This love of country is the only reason why the people of the Caucasus, the Alps, and the Pyrenees, who are, notwithstanding, so brave when they have to defend their native land, have never made any permanent conquests in neighbouring countries. After every victory they retire to their own narrow territories, separated from each other by transverse ridges of rock difficult to cross, and while they are dispersing, their vanquished enemies in the plain reconstitute themselves into powerful combinations. The pre-eminently victorious nations are those which inhabit monotonous plateaux or boundless low lands. The most extensive empire that ever existed was that of the Moguls; it extended from the Vistula to the Yellow Sea, and from the Frozen to the Indian Ocean; like swarms of locusts, the hordes became diminished in their course by battles and sickness, but none the less always kept marching straight on in their rage for massacring men and conquering territory. At the present time is not Russia the great invading power, and does a single year pass without her adding either the territory of a tribe or some fragment of a kingdom to her own enormous empire, already extending over the seventh part of the whole continental area?

Looking at the question in quite a general point of view, it may be said that the countries where the topographical outline acts most favourably on the nations which inhabit them, are the gently undulating lands of the temperate zone, where valleys well watered by streams and rivers alternate with hills, where the landscapes are beautiful, though not with a wild beauty, and the communications

are naturally easy. The largest part of France, Germany, England, and the United States present exactly these conditions, and that is one of the principal causes of the comparatively rapid progress made by the various peoples of these countries. Moreover, even in these lands where the race is renewed every day by the intermixture of families, where men and things are constantly mingling, and thoughts are speedily communicated from one place to another, it is easy to notice the contrast which is presented between the inhabitants of each region, according to the difference in the land and local climate. The people themselves never make a mistake, and are always able to mark out the frontier which separates two regions naturally divided. Thus, speaking only of France, the fact has often been recognized, that the outlines of the ancient Gallic *pagi* corresponded pretty exactly with the barriers of the geological formations, and in our time most of these *pagi* would again become reconstructed if an administrative centralization did not roughly oppose the action of natural affinities. Every soil brings forth its own special race; granite, calcareous soils, and even the region of lavas and extinct craters, wide fertile valleys and the belt of marshes and of sands are all alike in this respect. The popular name given to each province applies both to the soil and to the man who inhabits it; it explains and sums up the whole of the local geographical facts, and depicts the population itself with its physical features, its manners, habits, trade, and state of civilization. The natural harmony existing between the land and the people is so striking, that when we speak of Touraine, Poitou, Auvergne, La Marche and Limousin, Saintonge and Périgord, the Landes and Armagnac, we might almost fancy that we had before our eyes the aspect of these countries and the features of their inhabitants.

This very variety, this contrast between different provinces, forms one of the most important elements in the strength and prosperity of a nation, provided that these oppositions are not too numerous, and that they do not produce a violent breaking up into fragments and mutual antagonism, but are of a character to blend into one superior unity. Granite, chalk, sandstone, gravel, barren clays, sloping hills, moorlands, and sands mingle their various influences on the populations which inhabit them, and correct what may be too monotonous in the mind and manners of those who cultivate wide fertile plains. Agriculture may truly be said to be the mother of all civilization; labourers become attached to the soil from which they derive their own and their children's food; they detest wars which devastate their

fields like a storm, and burn down their cottages as if with fire from heaven; partaking of the nature of the soil which they cultivate, they are stubborn, patient, and quiet; from father to son, and century after century, they oppose violence and rage with a passive resistance which ultimately tires out the most energetic wills and vanquishes the proudest conquerors; they battle with the very elements themselves, and if a storm destroys their houses or a flood sweeps them away, they will resign themselves to famine, and depriving themselves of the corn on which they feed, will courageously sow it in the too deceitful furrow. Those high qualities are among those which are the most necessary in the work of the formation of a nation; but if the cultivators of the plains had not to undergo the various influences of the more restless populations of the hills, the table-lands, and sea-shores, further progress would ultimately become impossible for them.* As regular in their habits as the seasons in their annual course, rooted, so to speak, to the soil like the plants they cultivate, a mere routine would be their only law, their only ideal would be immobility, and their only hope in the future would be the maintenance of things as they were.

* See below, p. 214.

CHAPTER XVII.

INFLUENCE OF THE SEA AND RUNNING WATERS.—TRAVELLING AND COMMERCIAL NATIONS.—ISLANDS AND ISLANDERS.

THE ebb and flow of the waves exercise a great power of attraction on nearly all men, and must certainly be considered as adding a large portion to the population of sea-shores. Savages especially, who always obey their first instinct, yield readily to the fascination which water exercises upon them. In the islands of the Southern Ocean, which are still peopled by barbarous tribes, the sea-shore is the only inhabited part, and the villages form round the mountains of the interior a ring as regular as that of the banks of coral. It must be confessed that the islanders seek their food in the sea and on its shores, and the coast affords them the greatest facilities for trade and communication. The numberless fish and molluscs which frequent the sea in the vicinity of most of the coasts form an abundant source of food, which legions of fishermen may draw upon without fear of exhausting it. The shore and the waters which wash it form the readiest means of communication for the inhabitants, and allow them to go and exchange their fish for other commodities; we have here the beginning of commerce, and the origin of the modern movement which spreads in all directions across both land and sea, laying hold of the riches scattered far and wide, and circulating them from one to another like, as it were, the life-blood of nations.

These commercial facilities, which are enjoyed by the still barbarous people of many an island-coast, must exercise the same influence to a much greater extent over civilized nations, always anxious to be in relation with one another by the interchange of news and commodities. Thus the small islands of the West Indies, and the scattered isles in the Atlantic, as well as Mauritius and Réunion in the Indian Ocean, are inhabited almost exclusively on their outer edge; in many of these islands the interior remained a long time almost unknown, although the colonists, coming for the most part from colder countries, would have found it to their advantage to seek in the lofty valleys, and on the mountain-slopes, a climate similar to

that of their native land. In the same way, on the continent, considerable populations are massed in the vicinity of the coast, and not unfrequently a line drawn from any central plateau to the sea crosses regions increasing in population as it gets nearer the coast. In the interior of the country the people are in the habit of settling on the shores of lakes, which are, in fact, miniature oceans, or along the rivers and other watercourses, which the Chinese so rightly call "the children of the sea." Houses, gardens, and cultivated lands border continuously both banks of every large river in temperate Europe, and villages and towns are founded at every confluence where a tributary joins the principal watercourse; thus, as is often said, the Seine, the Thames, the Rhine, the Rhône, and the Loire are nothing but long moving streets, uniting one with another the fragments of the immense town which borders their banks from the source to the mouth. The lakes of Constance, Zurich, and Geneva are also surrounded by dwellings and gardens as though with a belt. Towards the eastern extremity of Lake Leman, from Vevey to Villeneuve, the *châteaux*, hotels, and country-houses connect one village with another, so as to form one splendid city; and certainly the beauty of the scenery, much more than the advantages of navigation, is the point which has made this lovely shore one of the most frequented and populous parts of Europe. The beautiful view of the verdant headlands, of the white shores, and the blue Mediterranean, is the cause why the coast of Liguria for more than thirty-seven miles in length, from Savona to Genoa and from Genoa to Chiavari, has been covered with palaces and marble villas.

Those who live immediately on the sea-shore, and from their dwellings can hear the noise of the waves, have generally a natural instinct to set sail upon them. The unlimited horizon which is spread before them inspires them with the love of space, and the never-ending succession of waves is constantly inducing them to rove over them. It must be confessed that when the coast is totally destitute of ports, bordered by sand-banks and rocks, and exposed to all the force of the waves and storms, the sea-shore populations cannot have that instinctive "soul of iron" which leads them to embark cheerfully on the surge in mere rafts or frail canoes; foreign nations, who are more favoured in the situation of their coasts and the tranquillity of their sea, are the guides from whom they must learn the art of building ships and guiding them over the waves. On the other hand, the inhabitants of coasts washed by waters which are nearly always still, and indented by harbours where vessels can take

refuge during a storm, give way to the instinct which attracts them to the sea, and the taste for travels and adventures is gradually developed. When the Spanish discoverers sailed for the first time along the coasts of Central America, they were surprised to meet with trading-canoes "almost as large as their galleys," and capable of carrying about fifty persons. And more than this, off the Peruvian coast the traders in jewels and stuffs were in the habit of venturing on mere rafts, and, allowing themselves to be carried along by the current and driven by the breeze, travelled hundreds of miles along the coast.*

Next to the exceptional advantages afforded to maritime populations by a large number of safe ports and a rarity of storms, the most favourable condition for the development of commerce and navigation among rising nations, is the vicinity of an island or archipelago, the dim outline of which is seen over the blue expanse of the sea, and invites from afar as if by some secret magic. In the same way, the timid fledgling flies out from its nest to reach the nearest branch. The islands of the Ægean Sea were the mid-points which attracted the mariners from Asia Minor towards Greece; and Cyprus appeared to the Phenicians as their first point of progress before they went out into the main sea. The island of Elba, hardly visible from the coasts of Tuscany, forms as it were one stage on the way to Corsica, the Balearic Isles, and the distant shores of Spain; in the same way the white cliffs of Great Britain, which sometimes appear above the Channel like a floating mirage, were a constant fascination, so to speak, to the inhabitants of the opposite shore, and this is the reason why, after having been so often invaded and conquered, she has ultimately become the principal commercial emporium of the whole world. Islands, those "pearls of the sea," are the features to which the surface of the globe owes some of its most charming aspects; and, thanks to commerce, these islands are likewise the cause to which nations are indebted for a great part of their civilization. As Ritter loved to repeat, it is difficult to imagine how the course of history would have been changed if the islands of Greece, Sicily, and Great Britain had never formed a part of Europe. If the Aryan nations had been deprived of citadels of this kind in which they could, as it were, shut themselves up, and so keep safely the treasures won by their intellectual and moral conquests, they would certainly never have attained the progress which has made the modern world what it is. Steeped in ancient barbarism, they

* Prescott.—Oscar Peschel, *Ausland*, No. 7, 1868.

would have remained strangers to one another; although the earth is so small, the whole of its circumference would never have become known, and mankind would still remain unconscious of its full power.

Nevertheless, before the navigation of the main sea had connected one with another all the points on the surface of the globe, islands could not fill any important place in the history of mankind, unless they were situated in the immediate neighbourhood of a continent, and depending, so to speak, on a land with rich plains and a numerous population. Islands, standing alone far out in the sea, are like prisons or places of exile to the tribes which inhabit them; even the very facilities they offer for voyages, the stimulus of the wind as it passes, blowing towards other countries, the fascinations of the waves with the mirage moving on them, the indistinct shapes appearing beyond the horizon calling to the mind's eye happy regions far away,—all become a cause of inferiority as regards social development, for when the islanders leave their little country to visit some distant land, they seldom return to their native soil. The want of a centre of attraction round which the inhabitants can gravitate, keeps them in a state of isolation and primitive barbarism. Just as in some of the lower organisms in which the head is wanting, life is spread generally over the whole body; but it is not concentrated in any one part, and cannot be very intense. Thus it is that those wonderful isles of Oceania, so numerous, so beautiful, and possessing such a fertile soil and delightful climate, have remained beyond the pale of the civilization of the world; scarcely two centuries ago they were still almost entirely unknown.

At the present time the regions best suited for the progress of mankind are, therefore, the wide continental plains which look out over the sea towards neighbouring islands and archipelagos. These fertile regions, which also, in most cases, have formerly been gulfs now filled up with marine or fluviatile alluvium, attract a numerous population. These countries with level soils are the spots in which agriculture developes itself, and the adjacent ports are those to which commerce is directed, where commodities are exchanged, and where men learn to know men and thought mingles with thought. Nearly all the mightiest cities are founded on the points where the sea-shore and agricultural regions come in contact; crowds gather there because all the great interests of humanity are there united. By a singular contrast, an agricultural population which is the most sedentary, and, by its mode of life, no less regular than the return of the seasons, and disposed to be the greatest slave to routine, is often found in

immediate contact with the maritime class, the most unsettled, the quickest in action and the fondest of travels and adventures. This juxtaposition of men so different in manners is one of the most important facts in the history of human progress.

There are maritime nations whose life is one continuous voyage, having made, as it were, the Ocean their home. Thus the Normans, who called themselves the "kings of the sea," were in the habit of sailing from shore to shore, carrying with them terror and destruction and conquering nations as they passed along; then re-embarking in their light vessels and crossing the vast tract of sea, they discovered the continent of America, which, after their time, remained five hundred years wholly unknown. A similar case is presented by the pirates of the Sunda archipelago, whose countless boats infest the waters of the Pacific, and who, although massacred in numbers, never cease to multiply as if they sprang from the waves. And where do those who are born on the shores of England pass the greater part of their lives? On the deck, under the mast, amid the rigging and the waves, scanning the clouds and the blue sky. Maritime peoples are always intrepid; they engage in too many terrible conflicts with storms, gusts of wind, and death under its thousand aspects, for them ever to tremble before their fellow-men; they are endowed with coolness and perseverance, for their struggle against the elements must often be a severe one; and, in order to conquer nature in all its fury, they require the courage of reflection more than that of enthusiasm. Their ideas are calm and energetic, but commonplace like the sea they sail upon: they rarely suggest to them either grace or gentleness, but strength and sometimes violence; as a child of the Ocean, the sailor presents in his life something like a reflection of the mighty billows on which he has been cradled since his infancy.

CHAPTER XVIII.

BLENDING OF DIFFERENT CLIMATES.—THE INFLUENCE OF CIVILIZATION ON THE FEATURES OF A COUNTRY.

Such, then, in an entirely general point of view, are the influences of various climates on the populations which inhabit them; such, too, are the ethnological contrasts produced by difference in zones, continental relief, aspect, and the nature of the soil. Nevertheless, these contrasts rarely present themselves in a distinct and decided manner; it is impossible to trace out the boundaries between nations with a ruler and compass. The influence of winds and currents, the presence of inland seas, the gulfs and promontories of continents, the curves of the mountain-chains, and the countless physical features of the earth, have a constant tendency to alter and intermingle the climates. In many cases even contrary forces tend to balance one another, and consequently the contrasts are weakened and die out. Thus, the ground is low in almost all the cold northern countries, and during the warm season it receives the whole salutary action of the sun; the inhabitants of northern regions, therefore, resemble the mountaineers on account of the severity of the climate which surrounds them, and the people of the plains on account of their low country. Further south, the mountaineer of the temperate or even the torrid zone may call himself a northerner because he lives in the midst of snow, or a southerner because the rays of the sun descend to him from the zenith and districts of exuberant richness lie spread before him at his feet. In the same way, if the peak on which he dwells rises from the midst of the sea, he may also be called a child of the Ocean, and his character will certainly exhibit some striking contrasts to that of the inhabitant of a mountain situated far in the interior of a continent. The endless varieties in water, air, and situation, and the more or less rapid vibration of luminous and magnetic waves, are constantly modifying the general aspect of nature. Every province, city, and hamlet has its own peculiar climate, and this climate again has nothing permanent about it, and varies every moment. All

climatic facts demonstrated by observation blend into one another, and consequently it is impossible to judge of their action on nations except from an entirely general point of view.

And this is not all; nations do not rest for ever on the soil where they were born, but between them and their neighbours there is always taking place a more or less active interchange of isolated individuals and of families; sometimes, indeed, nations are forcibly united by conquerors who transplant whole peoples; or else, the vanquished go and seek a new country beyond the seas or mountains in a totally different climate. In this case the climatic forces come into action and modify the primitive type of the man thus removed from his native soil, and substitute for him a new type more in conformity with the nature which surrounds him. This struggle between the past and present, between men and climate, and not the account of the battles of armies and the crimes of kings, are the facts which constitute real history, that is to say, the evolution of man in his connection with the globe.

Moreover, even if nations do not change their country nor intermingle with other nations, their wants and habits become modified with the various changes in the state of society, and consequently the influence of the nature which surrounds them varies century by century. Thus great forests, where the number of inhabitants depends totally on the quantity of game, are no longer suitable to man when he becomes an agriculturist; trees fall under the axe, and the continually widening clearings are filled with corn-fields; the climate changes and reacts on the populations who crowd into the cleared areas. The reclamation for cultivation of steppes, low and marshy lands, and all formerly desert regions, also results in modifying the surroundings and the people who live there. The great navigable rivers, with their whole network of streams and canals, are scarcely made use of by uncivilized tribes, and, only to adduce one instance, the immense river of the Amazons, the most magnificent track for commerce possessed by the interior of any continent, has scarcely during past centuries exercised any appreciable influence on the development of civilization among the populations on its banks.* By means of trade, rivers on the contrary become to civilized nations the principal material agents of progress, until the creation of more rapid and artificial ways of communication have lately diminished the comparative importance of the roads afforded by nature. We find villages grouped along the great highways, even when the

* Oscar Peschel, *Ausland*, 1868.

latter do not run through the middle of the valleys but traverse plateaux exposed to the wind and destitute of the water necessary for use; occasionally, indeed, the whole road seems converted into one long street, every peasant desiring to live on the line along which foreign traders pass. Railways, also, have their part in the movement of population, and each station becomes an attractive centre round which all the inhabitants crowd. Beds of metallic ores, deposits of coal, marble, gypsum, salt, and other riches contained in the earth, are also, according to the state of civilization, treasures either unknown or neglected, and are elements either useless or of the highest importance in history. California, a district almost unknown five-and-twenty years ago, has, owing to its gold-mines, become one of the greatest centres of activity on the surface of the globe.

Fig. 191.—Villages of Allemont.

Even the raised outline and the general disposition of countries may be in turn either useful or disadvantageous according to the various epochs in the life of nations. Thus the barbarous peoples which preceded us on the soil of Gaul and the other countries of

Europe, took refuge in caves among the rocks, or built their huts on piles driven into the bed of some lake. Subsequently, when a continual war of ambuscades and massacres between neighbouring tribes had given place to a somewhat less troubled state of society, the troglodytes came down one after another from their gloomy caves; the lake dwellers left their unhealthy roosting-places and settled on *terra firma* under the shade of the wide-spreading trees; the water of the lakes, which formerly protected them from all attacks, had now become a danger to them by separating them from the land where they found the means of existence. During the terrible iron ages of feudal life, the great lords erected their castles like vultures' nests on the summits of impregnable rocks, grouping the humble cabins of the peasants at the foot of their lofty ramparts; the towns themselves no less than the castles were confined to the crest of some declivity very difficult of access. At that time the primordial care being that of defence, each group of habitations was placed at the summit of some lonely peak, surrounded by walls and bristling with towers. In the south of France, in Spain, on the coasts of Liguria, in Tuscany and Sicily, nearly all the old villages are perched up on the heights, and looked at from below, their crumbling walls resemble fantastic escarpments of the rock; the houses built up on the outer rampart have no windows but the narrow defensive loop-holes; the corner buildings are battlemented and machicolated towers furnished with portcullises; the church built on the highest point forms also the citadel of the village. But in modern times the first requirement is that of labour; the inhabitants, therefore, abandon one after the other their eagle-like eyries and go and settle on the sea-shore, the banks of some river, or the edge of the roads which pass through the plain. Like those sea-animals which get rid of a shell that has become too small for them, they emerge from their picturesque turrets and build themselves dwellings, less beautiful perhaps as a detail in the landscape, but much more healthy and comfortable.

Even in the least civilized countries of Europe the towns have been transposed from their lofty summits and have been established near the sea-coast. On the northern coast of Sicily, every *marina* increases at the expense of the *borgo*, and the old town ultimately becomes a splendid ruin, rising like a mass of rocks on the crest of the lofty mountains. There are still, however, towns containing several thousands of inhabitants situated on mountain-ridges far above any cultivated lands; thus, in Sicily we have Monte San-Giuliano

and Centorbi. The former, built on Mount Eryx, formerly sacred to Venus, occupies a narrow plateau 2300 feet above the sea and the plains of Trapani. The town of Centorbi commands the plain at a

Fig. 192.—Monte San-Giuliano.

height of more than 3280 feet. The inhabitants who cultivate the fields lying at the foot of the mountain are obligod every day to go up and down an endless flight of steps winding in among the rocks and hemmed in by precipices. In front, on the other side of the valley of the Simeto, and at the edge of a stream of lava which has run down from Mount Etna, stand the mansions of Adernó. The clouds which float across from town to town traverse this space in a few minutes; standing on the edge of the cliff of Centorbi, one may even inhale the perfumes of the gardens on the opposite terrace; but to accomplish the distance separating the two localities the time needed is as great, or greater, than that required to travel from Paris to the Belgian frontiers or to the coasts of the Channel. It is evident that a state of things like this must shortly be altered. The citizens, who shut themselves up every day within their ancient walled inclosures, need not now feel any dread in establishing themselves in the midst of tracts of land at present uninhabited. The steep-

ness of the escarpments and the difficulty of access, which were formerly esteemed by them as a privilege when their life was one continual terror, ought henceforth to appear, that which they are in reality, a most disadvantageous loss of time and a deplorable cause for an inferiority in civilization. The summits of lofty mountains will no longer be favourite sites for the building of towns, until man has become a lord of the air by being able to steer balloons, and until the most favourable landing-places for him are peaks and ridges.

These successive changes in the more or less considerable adaptation of the earth to the nations inhabiting it, take place no less in respect to the outline of the continents themselves than in the trifling details of local topography. Thus, the numerous bays which run into the coast of Europe, and the peninsulas which project in every direction, and contribute so largely in giving to the people of this part of the world the first character in history, are constantly losing in comparative importance, in proportion as the inland ways of rapid communication increase; it may even be asserted, that in all countries now intersected by railways the indentations of the coast, once so useful, owing to the natural water-ways they presented for navigation, have become an obstacle rather than an advantage. Thus, until lately, great commercial ports were necessarily fixed at the land-side of the hollow formed by the shores of a gulf, or else on the banks of the estuaries which run the deepest into the continent; for this position enabled them to receive, by the shortest possible road, the largest possible quantity of commodities and merchandise from neighbouring countries. In our time, owing to the rapid means of communication, this is no longer the case, and maritime commerce tends more and more to take for its starting-place ports situated at the extremity of a peninsula. Every historical progress, therefore, changes the relation of man to the earth which he treads, and consequently the influence of his surroundings is incessantly being modified.

CHAPTER XIX.

THE COURSE OF HISTORY.—HARMONY EXISTING BETWEEN COUNTRIES AND THE NATIONS INHABITING THEM.

It is the duty of historians to relate the course of nations across continents and islands, and to point out the incessant action exercised upon them by soil and climate. Every mountain, every headland, every islet, every lake, river, or rivulet plays its part in the history of mankind. Nevertheless, the earth itself and the events which have taken place upon it are too little known for it to be possible yet to attempt a detailed description of the harmony existing between the human race and the globe during past centuries; it is only possible to point out the chief features of the part which the principal regions of the globe have taken in the development of nations.

The vast and compactly formed continent of Africa has not afforded its inhabitants the opportunity of forming relations with other populations of the globe; in the north only, the Berber tribes occupying the slope of the Atlas facing the Mediterranean, and separated from the rest of Africa by the great desert, have been associated in a slight degree with the movements of European civilizations. With regard to Egypt, whose influence has been so great over Greece and the eastern world, it must be considered as forming a little world by itself, to which the remainder of the continent was as an unknown land. In the vast inaccessible area of equatorial Africa, men were born and died generation after generation, without knowing that other men like themselves lived beyond the boundaries of their country; in their view the entire universe was comprised within the limits of their horizon. Favoured by constant heat and fertile lands, they had not sufficient ambition, and did not tax their ingenuity to render their life more easy. Left to their own resources, they lived as their ancestors had lived; during the course of centuries, therefore, civilization could make but imperceptible progress among them. Almost up to the present time, as is well known, most of the inhabitants of Africa, belonging to totally different races, Caffirs, Hottentots, Congos, Mozambiques, Achantis, Peuls, and Yolofs, have remained in a state bordering on primitive barbarism.

The numerous archipelagos scattered over the Pacific Ocean must, on account of their dispersion, have been as unfavourable to the rapid progress of their inhabitants as was the enormous pile of Africa, on the other side of the world. Previous to the discoveries of modern navigators every island in the Southern Ocean was a small separate world, where, owing to the fertility of the soil and the beauty of the scenery, a rudimentary society was developed; moreover, the facility afforded for navigation in these seas, which are generally smooth and swept by regular winds, enabled the migration of tribes to take place to a very considerable extent. But no sooner were these new connections formed than the old ones were broken off; the savages who had repaired to their fresh country were for ever separated from the former one. In consequence of the fatal isolation of the various groups of people, no great mutual interest and no idea in common can link together all the tribes of the Pacific. This portion of mankind imprisoned, as it were, in the different islands, has remained broken into fragments never destined to be reunited.

In the east of Asia the inhabitants of the coast of China and the islands of Japan were more fortunate than the islanders of the Southern Sea. In these countries of the Old World the fathers could at least bequeath to their children their industrial skill and their acquirements; tribes could unite with tribes, and nation could instruct nation. The "central flower of the earth," that region vast enough to maintain hundreds of millions of inhabitants, is also in possession of numerous privileges; it slopes gently towards the sea, it is watered by wide navigable rivers, its sea-coast is indented by bays and promontories, and its temperate climate incites to labour by a regular alternation of seasons and crops. The insular part of this region is composed of an archipelago of several thousands of isles, and islets are grouped round the larger tracts of land; the communication between these islands and the continent itself is always easy. Thus the peoples of China and Japan have, by their own inherent energy, attained to a very advanced state of culture, and for a long series of centuries they were probably the foremost among mankind in respect to agriculture, commerce, trade, and practical philosophy. This civilization in the extreme east had, however, no outlets except towards the almost solitary tracts of the Pacific Ocean. On this side the access to other continents and other nations was closed to the influence of the yellow race, and savants have cogent reasons for doubting the fact that, during the course of historic ages, any Chinese emissaries ever crossed the Southern Ocean

and carried into the land of Fu-sang, now called Mexico and Guatemala, their religion, manners, and architecture.

The tracts of land which extend obliquely across the Old World from Ceylon and the banks of the Ganges to the British archipelago, owe to the favourable form of their outline and the harmonious distribution of their mountains advantages as great as, but different from, those of China and Japan. Descending from the plateau of Pamir and the circumjacent districts towards Hindostan, Bactriana, and Asia Minor, the Aryan race did not become divided into completely isolated nations. In spite of the lofty mountain-chains of Soliman-Dagh and Hindoo-Koosh, in spite of the salt plateaux of Persia and the cross ridges of Elbury, Ararat, and Taurus, the communications between adjacent countries were never interrupted, and the industrial and moral attainments of the people did not remain absolute secrets to their neighbours. Whilst each peculiar mode of civilization was worked out in its own special domain, it profited from those which were springing up afar off on other plateaux or on other plains; the myths and the songs of India, bequeathed by the ancient Aryans, were known to the Persians, and the thoughts of Persia flowed back to the Hindoos; lastly, the religion and philosophy of both one and the other, modified in their passage through time and space, were mingled and blended with the civilization of the Semitic nations, the Chaldeans, the Phœnicians, the Jews, and the Carthaginians.

On the shores of the Mediterranean, the two countries of Egypt and Asia Minor, which bound the eastern part of this great sea, are the principal representatives of the first era in western civilization. In these two countries the state of society exhibited the most opposite contrasts in consequence of the variety of races, manners, and climate; but wars, commerce, travels, extensive migrations, and lastly, science, were constantly tending to connect the two poles in the world's civilization. The union of the two contrary elements commenced in the beautiful country of Greece, and then advanced further on to Crete and the Cyclades, as if to serve as a rendezvous for the ships of Egypt, Phœnicia, Cyprus, Ephesus, and Troas. The ideal of all that the ancient communities had dreamt of as the great and the beautiful was realized in the little peninsula of Hellas, an harmonious combination of mountains, deep valleys, and peninsulas scarcely noticeable on our maps, and yet the part of the earth where, up to our time, the glory of man shone forth in its greatest splendour. Nowhere else on the face of the globe does the earth assume forms so harmonious, and,

so to speak, so living. The mountains, although of no great height, exhibit an outline of such great beauty, that they still retain their celebrity by the side of the giants of the Alps, Andes, and Himalayas; and the names of Monte-Rosa, Antisana, and Gaurisankar, will never perhaps shine out with the same glory as those of Pindar, Citheron, Parnassus, and Olympus, the abode of the gods. On a diminutive scale, the small country of Greece exhibits, as it were, a summary of all continental features; it has its plateaux, its piles of rock, its mountain-ranges, its valleys and plains, visible and invisible watercourses, lakes, and gulfs; the ancients indeed went so far as to find there both heaven and hell. Its shores are curved into so many gulfs and bays, that the terminal peninsula resembles a dentated leaf floating on the waters. Every city had its river, an amphitheatre of hills or mountains, fertile fields, and an outlet towards the sea; every element necessary for the free association of men was there combined, and the neighbourhood of rival cities, equally favoured, kept up a constant spirit of emulation. Thus there never has been seen in the world any groups of republics so proud and so favourable for individual scope of ambition. The little town, rendered illustrious by Æschylus, Sophocles, Phidias, Demosthenes, Plato, and many other men of genius, is still, after a lapse of more than two thousand years, the bright centre of history.

At the time when the Hellenic republics were at the zenith of their glory local civilizations sprang up in Italy, Sicily, Iberia, and Gaul. In consequence of the geographical position of these countries, all the intellectual and moral conquests of Greece and the East turned to their profit. By small degrees, and century after century, an irresistible march of ideas continued its course from the plains of Hindostan to those of western Europe. The revolutions in the history of modern nations are well known; we know also how, after having succeeded in passing through, without extinction, the long and gloomy night of the middle ages, mankind was "born again," owing to a twofold discovery which gave the societies of modern times a definitive scope of action. Whilst poets, scholars, and men of science were recognizing in the treasures of antiquity the free thought of Greece and the incisive genius of Rome, Columbus and other navigators were discovering the two continents of America, and thus completing the equilibrium of the globe. From that time the gradual civilization of all nations was assured, both by science and justice, in spite of violence of all kinds, wars, and hideous ignorance. The progress of each nation became that of

GREECE.

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mankind itself; all the islands and all the continents once separated from one another were united across the Ocean and became the common domain of man. At the very time when, owing to the discoveries of Copernicus, Kepler, and others, the earth, which was supposed to be limitless, was found out to be nothing more than an isolated globe, revolving in space, and no longer the centre of the universe, the inhabitants of this inconsiderable planet began to feel the consciousness of their own greatness, and out of this mass of nations and tribes one common humanity began to assert itself.

In consequence of that movement of civilization which, in the Old World, spread from east to west, following the course of the sun, the ports of Western Europe, Cadiz, Lisbon, Bordeaux, Nantes, Saint-Malo, London, Bristol, and Liverpool, are like so many conductors from which the electric fluid flashes forth to cross the seas to the American continent. But there the movement must necessarily change its direction. The New World is not, like all great historic countries, placed in a parallel line with the equator; but, on the contrary, it extends from north to south in the direction of the meridian, and, thanks to this transversal position, European emigrants have been enabled rapidly to colonize the lands recently discovered. Italian, Spanish, Portuguese, French, English, and Dutch navigators all found, both to the north and south of the equatorial line, regions with a climate similar to that of their native land, and in both zones they were able to found a "New Spain," a "New France," and a "New England." Added to this, both winds and currents cross the Atlantic obliquely, and bear the mariner towards those wondrous regions of the Antilles and Columbia, where nature, notwithstanding the heat of the climate, exercises so great a fascination over European strangers.

Emigrants from the Old World have thus established themselves all along the coast of the new continent for a length of more than 6000 miles, from the estuary of St Lawrence to that of La Plata. At the same time, the breaks in the chains of the Cordilleras in the isthmus of Central America enabled emigrants to colonize the western shores, also those which face towards China, Japan, and Australia. Thus invading the whole length of both continents, the new comers have been able to go on and conquer the interior of America; they have made themselves acquainted with its vertical outline, with its soils and with its products, and these are now better known than the features of a great part of the Old World, and they have founded in these but lately unexplored regions societies allied to

those of western Europe. The children of the emigrants have become nations, the power of which has prodigiously augmented when compared to the progress of the mother-country. In these virgin countries, population, manufacture, commerce, public riches, all increase with unheard-of rapidity, and it is an important fact in the opinion of some that the United States of America, to some extent disentangled from the oppressive institutions of ancient Europe, govern themselves by free democracies. The "Utopias" of the Old World have become realities in the New World. America is the laboratory where the European ideal is brought into practical action for the public good.

The two Americas present a harmonious counterpoise as regards their continental masses, and in a social point of view exhibit a contrast which may be compared to that of their shapes. The northern portion, situated between Europe and China, is admirably organized to serve as a great thoroughfare for nations and merchandise travelling from the far east to the extreme west. Through it now passes the Pacific railway, which continues on *terra firma* the line of steam-boats which, on one side, run between New York and Liverpool, and on the other between Shanghai and San-Francisco. In the interior of the northern continent, the inland system of great lakes and the gently undulating plains of the Mississippi afford to commerce and colonization facilities unequalled in any other part of the world. Nevertheless, the population which forms the United States is almost entirely composed of emigrants of European descent, and, unfortunately, it has not as yet been able to blend either with the aborigines or with the race of slaves imported from Africa.

South America is a continent of a more maritime character, and its ports, opening on the great southern seas, serve as intermediate landing-places in voyages of circumnavigation. In the interior trade and colonization find a province less favourable than that of the northern continent; the mountains there are loftier, the plateaux rise more steeply, the forests are more difficult to cross, the deserts are more inhospitable, and the climate is more to be dreaded by emigrants from distant Europe. Thus, the South Americans have suffered more than their northern rivals from the influence of their surroundings. Without relinquishing their brotherhood with the nations of the Old World, they have gradually become mingled with the natives, and this fusion of races has been

the means of introducing those who were once savages into the sphere of modern civilization.

North America may be more European, more characteristic, and more active in its character, but South America addresses itself more to the whole human race: to her belongs the honour of having invited many a still barbarous tribe into the great unity of nations.

BOOK IV.—THE WORK OF MAN.

CHAPTER XX.

REACTION OF MAN ON NATURE.—EXPLORATION OF THE GLOBE.—VOYAGES OF DISCOVERY.—ASCENTS OF MOUNTAINS.

WHILE society was in its infancy men, either alone or grouped in small tribes, had to fight against obstacles too numerous for them ever to dream of appropriating the surface of the earth as their own personal domain; they lived on it, certainly, but they timidly concealed themselves in its recesses like the wild beasts of the forest; and their very life was a constant struggle; being continually threatened either with famine or massacre, they were unable to devote any attention to the exploration of the country in which they lived, and those laws which would have enabled them to utilize the forces of nature were still unknown to them. Still, in proportion as nations became developed in intellect and liberty, they learned to exercise a counteracting agency on that outer world, to the influence of which they had passively submitted; they gradually appropriated to themselves the soil on which they trod, and having become by dint of association actual geological workers, they altered in various ways the surface of continents, changed the system of running waters, modified the very climates themselves, and shifted the habitat of the different faunas and floras. Among the works which animals of a lower order have accomplished on the earth, the islets built up by the coral-animal may, it is true, be compared with the works of man as regards their extent; but these constructions are uniformly continued century after century, and never add a new feature to the general physiognomy of the globe; we always find similar kinds of reefs and similar tracts of land, emerging from the ocean like beds of fluviatile or marine alluvium; whilst the works of man are incessantly being modified and give the greatest diversity of aspect to

the earth's surface, renovating it, so to speak, with every fresh advance of his race in knowledge and experience.

The principal of all the conditions which will some day enable man to completely transform the surface of the globe, is that he must become fully and entirely acquainted with it and traverse it in every direction. Formerly, the savage or barbarous tribes, living entirely separate from one another, formed nothing but chimerical ideas as to the territories lying beyond the narrow boundaries of their own country; they fancied they saw there nothing but an empty and limitless space, a gloomy and formidable world peopled by monsters, but where man himself could not live. All the most remarkable features on the surface of the globe remained utterly unknown to them; the inhabitants of the plains imagined the whole earth to be one great level tract of land, whilst those of mountainous regions pictured it to themselves as a succession of narrow gorges, cliffs, and summits. In the same way it appears that the Zunis, who lived far from the sea-coast in the deserts now called New Mexico, were ignorant of the very existence of the ocean; on the other hand, numbers of the islanders of the South Sea were totally unaware that vast continental masses, extending over an area of many thousands of miles, divided the seas into separate basins. According to the testimony of Franklin, the Esquimaux learned with astonishment, that towards the south lands existed perfectly free from ice, and under the equator the ignorant inhabitants of the banks of the Amazon innocently imagine that their enormous river flows all round the world.

In proportion as, by means of trade, travel, and even warlike expeditions, nations came to know the territories belonging to one another, they banished the idea of monsters into the mysterious spaces extending beyond the boundaries of the explored world; the sphere of knowledge increased simultaneously with the regions traversed, and the fanciful beings, such as gnomes or giants, who were supposed to retreat either towards the north or the south, bore away with them many of these superstitions and erroneous ideas. Thus the Greeks, who are represented to us by their mythology, as contending in the earliest ages against centaurs and dragons, in the time of Aristotle and Plato fought only with men like themselves; and they localized the fantastic figments of their childish imagination at points many hundreds of days' journey away on the other side of the Ganges and the columns of Hercules, in the burning deserts of Libya or near the Hyperborean mountains. Thus, in the middle ages,

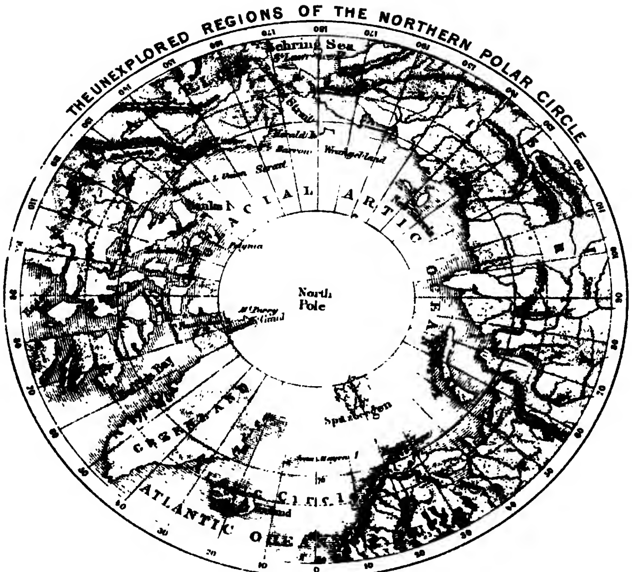
and even down to modern times, our maps of the world, like those of the Chinese and the Japanese, represented all unknown lands as inhabited by monsters; but every new discovery made by travellers contracted the domain of fable, and quite recently the last mythical beings of geography, the tailed Niam-Niams, have finally been made to disappear from the centre of Africa.

Since the time when man first went round the world, that is to say, three centuries and a half ago, explorers have no longer had to venture into any region completely unknown: all they had to do was to connect with one another the lines of travel already traced out on the surface of the globe. This network of innumerable intersecting lines covers nearly the whole of the great continental masses and extends over all that portion of the sea comprehended between the two polar circles; only towards the north pole, and on the opposite side of the earth in the antarctic regions, there still exist areas extending over a space of 2,900,000 and 8,700,000 square miles respectively, which icebergs and mountains of ice have, up to the present time, kept intact from any exploration.* Those spaces which still have to be explored at the two poles form nearly one seventeenth part of the surface of the earth, that is to say, a tract equal to about sixty times the area of France; in those regions there is still a very considerable extent of unexplored land and sea, and even in our days a few pusillanimous geographers have expressed a fear that these districts will remain for ever unknown. Captain Cook, the brave navigator of the Frozen Antarctic Ocean, asserted that no one had or even could approach any nearer to the pole than he had done. Pigafetta, also, in his account of the great voyage which he took with Magellan, gives as his opinion, "that in the future no sailor would be bold enough to brave the dangers and fatigues of another circumnavigation of the world." It must certainly be confessed that fifty-six years elapsed before another sailor, Drake, brought to a happy termination a second voyage round the world; in the present time nothing is thought of such voyages, so often are they accomplished.†

The energy with which the explorers of the polar regions have undertaken and are always ready to recommence their perilous voyages across the ice is a sure guarantee of their future success; for though the obstacles remain the same, the experience of sailors and the resources of science are ever increasing. The discoveries

* *Mittheilungen von Petermann*, 1868.

† Oscar Peschel, *Geschichte der Erkunde*.



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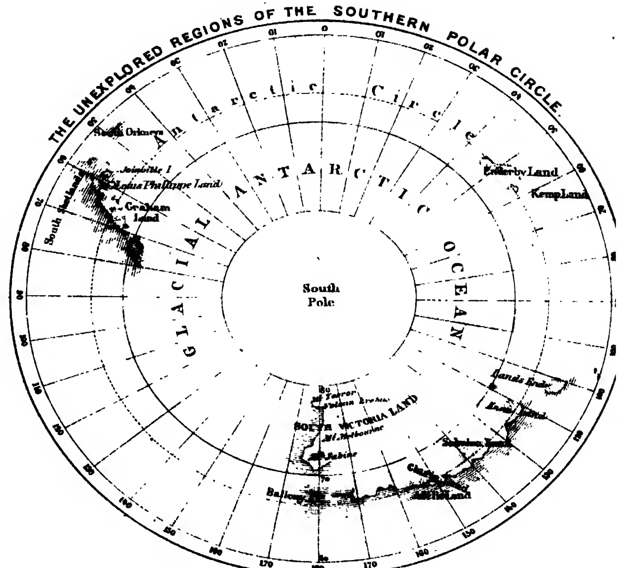

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which have still to be made in the centres of the vast continents of Asia, Africa, South America, and Australia, cannot fail to be accomplished before very long; for most of the difficulties which impede travellers are of the moral order, and will gradually disappear, thanks to the progress of commerce and civilization. The horrible trade which makes the white man so justly abhorred in the centre of Africa, as well as in the basin of the Amazon, will soon come to an end; the tribes once appeased will welcome the explorers and supply them with guides; groups of colonists, advancing by stages across continents, will form links of connection between the districts inhabited by civilized races. Every year, the spaces of land we still have to examine and trace upon our maps are diminishing in size, and hundreds of heroes, numbers of whom are destined to die in obscurity, are still further endeavouring to narrow them. The most extensive surface which up to the present time has remained untrodden by the feet of European explorers, is that part of the African continent which is comprised between the sources of the Nile, the Congo, the Ogobai, and the Benue.

When man at last becomes acquainted with the whole surface of the globe of which he styles himself the master, when Columbus' saying is realized, "*El mundo es poco,*" (the world is small!) the great geographical work will then be, not to explore distant lands, but to thoroughly study every detail of the country which we inhabit, to make ourselves acquainted with every river and every mountain, and to point out the part taken by each portion of the terrestrial organism in the life of the whole. This work, at the present time, is the task to which most of our savants, geographers, geologists, and meteorologists are specially devoting themselves, and important societies are being formed in every direction in order to push on local explorations. These societies address themselves most of all to the mountains which rear their glittering summits far above populated slopes, where no mortal foot has yet surmounted the snow. Every year several of these hitherto inviolate peaks are successfully scaled by travellers, who point out to their friends the road they must follow in order to surmount them; these small spots elevated into the glacial regions of the air can no longer escape the investigations of man any more than the vast tracts in the arctic and antarctic zones. The English may lay the chief claim to the honour of having given the first impulse to the desire for exploring so many lofty summits. It is now a hundred and twenty-five years since Pocock and Wyndham discovered, so to speak, Mont Blanc. Since that memorable epoch

individuals of the English nation are still those who, surpassing in zeal and intrepidity the very inhabitants of the Swiss Alps, and even the Savoyard, Italian, and French mountaineers, have made the most frequent ascents of Mont Blanc and the other giants of the Alps; it is the English, too, who have investigated with the greatest ardour the Mer-de-Glace and the various glaciers of the western continents, and have explained to us the actual topography of the almost unknown ranges of Pelvoux, Grand-Paradis, and Viso; it is they, too, who, by the foundation of the first Alpine Club, have since given rise to a great number of societies of the same kind in the different countries of Europe. Lastly, they have just established at Lahore a "Himalaya Club," in the hope of being able some day to surmount in turn all the lofty summits of Central Asia, which are double the height of the European giants.

CHAPTER XXI.

RECLAMATION OF THE EARTH BY CULTIVATION.—ANCIENT AND MODERN IRRIGATION.

Long before man had made the soil of the earth his own by science he had commenced to adapt it to his use by cultivation. The various tribes of hunters and fishermen, like the nomad shepherds, did nothing to modify the aspect of the earth, and if their race had become extinct, no vestige of them would have pointed out their existence on the surface of any continent; but as soon as families permanently settled down where vegetables might be grown for food, and learnt how to plant trees and to sow seeds and fruits, the work of transformation was inaugurated. Every spot of the earth where plants useful to man, such as cereals and fruit-trees, had taken the place of other vegetable products which were cut down by the axe or cleared by burning, has become a centre round which cultivation has spread from place to place, till in the present time, thanks to the hundreds of millions of men who unceasingly labour in order to draw out the productive forces of the earth, immense tracts have completely lost their primitive aspect. The total extent cultivated by the hand of man, and divided into fields with regular boundaries, may be estimated at 2900 million acres, that is to say, about one tenth part of the continental surface. It must be confessed that by far the greatest part of this vast tract of land is worked rather by a system of extortion than properly brought into cultivation.

In countries which possess soils of a naturally salubrious and fertile nature, and are not yet inhabited by a numerous population, selection is the only difficulty experienced by the agriculturists, and the soil which they cultivate is of that kind which produces abundantly without any need of fertilizing it by manures. Thus, in the United States, where there are more than 860 million acres of unoccupied ground still at the disposal of the citizens, the colonists cultivate little else but alluvial plains, the land bordering rivers, and valleys watered by running streams. On the other hand, in the countries of the ancient world, where the crowded population is

beginning to feel the want of rich soil, a great variety of soils, which anywhere else would be despised as unfruitful, is made to form a part of the domain of agriculture, and sooner or later becomes covered with crops. There is no soil that man, impelled by necessity, and having at his disposal the enormous resources which are afforded him by the combined efforts of science and industry, cannot transform into fertile fields: by means of drainage, he draws off the hurtful water which chills the earth and rots the roots of plants; by means of irrigation he brings on the land at the proper time the water necessary for the development of sap and tissues; by means of manure he enriches the soil and nourishes the growing plants; and by these and other improvements he changes the nature of the very soil. Agriculture, which was formerly carried on quite at random, is tending more and more to become a science, and it will become a perfect science when the laws of chemistry, natural philosophy, meteorology, and natural history are thoroughly understood.

Among the great agricultural undertakings already accomplished solely through the sheer perseverance of the peasant, without even the assistance of the resources of modern skill, there are some which are truly admirable. For example, what could be more wonderful than the hillocks on the banks of the Moselle and the Rhine, or the hills of Provence, Liguria, and Tuscany, which, from the base to the summit, are encircled by wide concentric stages, each of which are covered with crops of vines, olive-trees, or corn? The pickaxe and spade have broken up the loose rocks, and the debris have been used to construct this huge staircase of walls, each of which, like the terrace of a garden, keeps back the vegetable soil and prevents it from crumbling down the declivity of the rock. Should a storm breaking over the mountain overthrow their walls and devastate their pieces of ground, next day the peasants are to be seen hard at work reconstructing the stages, while others—and the women generally perform this task—toil up from the foot of the mountain bringing back basket-full by basket-full the precious mould which had been carried away by the storm. How contemptible the celebrated hanging gardens of Babylon must appear when compared with these prodigious monuments of human labour!

The slopes of the Mediterranean volcanoes also present remarkable instances of what may be done by the persevering will of the cultivator. On the very sides of Etna, the summit of which rises far into the region of perpetual snow, more than 300,000 inhabitants have their abodes. The soil of the fields, which are shaded by mul-

titudes of fruit-trees, is composed of nothing but lava and ashes; but hard and daily work has transformed it into a garden which is the wonder of Sicily. The peasants set stubbornly to work at every rock, and step by step have reclaimed them and transformed their rough uneven surface into vegetable soil. When the mountain breaks forth into an eruption, and vomits out lava over the crops and the villages, agricultural labour is merely stopped for a time. Families religiously preserve their rights of property, just as if the property itself had not disappeared; then after the lapse of few or many years, as soon as the cooled lava is covered here and there with patches of lichens, the agriculturist sets to work in order to utilize the smallest crevices of the rock which offer facilities for vegetation. Certain compact lavas, particularly that which destroyed a portion of Catania in 1669, can only be broken up by a singularly slow process, and in order to cultivate the upper layer of the scoria during the course of the same century, it was necessary to pulverize them and mix them with fertile mould; nevertheless, industry ultimately succeeded, and gardeners planted there shoots of the cactus, which grew up very quickly and hid the reddish-coloured earth behind the impenetrable thickets of their thorny leaves, which shine in the sun with a metallic brilliancy. Fig-trees creeping along the ground insinuate their long roots into the interstices of the rocks. In certain spots even the vine thrives and bears fruit on these hard scoriæ, which look almost like blocks of iron. Other kinds of lava, on account of the friability of their texture, and the quantity of ashes which are blown on to them by the wind, are adapted for a rudimentary kind of cultivation in the space of a few years. Of this kind are the lava-flows of Zaffarana, which burst from the bosom of the earth in 1852 and 1853; in the hollows the inhabitants of the villages planted some brooms and furze within five years after the eruption.* But whether the scoriæ of lava be either friable or hard, they will nevertheless ultimately become transformed into vineyards and gardens. As persevering as the ants, who seem never weary in rebuilding the heaps destroyed by the feet of those who walk over them, the peasants of Mount Etna begin again from century to century their persevering work, and after every flow of stone which covers their fields, they lay out new meadows no less verdant than the gardens which had disappeared.

Among all the agricultural works which have changed the aspect of the earth, channels of irrigation are those which, in past ages,

* Charles Lyell, *Philosophical Transactions*, 1858.

have been the most magnificently planned and carried out. The Egyptians, blocked up by the sand of the desert, and setting their hearts, so to speak, upon the mud of the Nile from which they believed their ancestors had sprung, made irrigation one of their great sacred rites; their reservoirs which were dug out for the management of the flood-waters must have required as much labour as the useless ostentatious pyramids.* In Lombardy and Tuscany, also, the general irrigation of the country, under the direction of syndicates, was practised with great skill, and the grandest names both of artists and savants, such as Leonardo da Vinci, Michael Angelo, Galileo, and Torricelli, are associated with the history of this portion of the art of agriculture. In the present time this work is being carried on with great activity in all the countries of the south of Europe, and in many other regions of the world which are liable to suffer from aridity. Before they emerge on to the plains, nearly all the mountain-streams of Piedmont, Provence, Roussillon, and Mediterranean Spain, are almost entirely drawn off on to the fields, and only during showers or the melting of the snow the stony beds are filled up with muddy water which the thirsty land very soon absorbs. Great rivers, such as the Po, the Nile, and the Durance, which are utilized for irrigation, diminish in quantity of water every year; and if the ambition of agriculturists is realized, they will ultimately disappear altogether. Love the engineer, is desirous that all the rivers of France should be done away with as soon as possible, by drawing off the tributaries at their source, and by shutting them up in channels for irrigation, so that they should be made to follow all the windings of the ground.†

Moreover, at the present day we are no longer contented with surface-water for the moistening of the earth. By means of boring, man seeks to obtain the water which flows in the depths of the earth, and to force it up to the surface in order to irrigate his plantations: this has been most successfully carried out in Algeria, either with a view of increasing the extent of existing oases or to create fresh ones; no doubt this operation might likewise succeed in other countries where underground streams are hidden beneath the arid soil. And this is not all; that water which is diverted from its natural course or is made to gush forth from the bowels of the earth, acts upon plants not only by supplying them with the necessary moisture, but also by means of the various fertilizing matters and

* See in *The Earth* the chapter entitled, *Rivers*.

† Société des Ingénieurs civils, *Discours d'inauguration*, du 1st Janvier, 1868.

manures which it carries along with it. On the fields over which it flows it spreads the alluvium derived from formations of different natures, and thus tends to blend various soils, a process which is very advantageous for vegetation; by the process of "warping" it changes naturally poor ground and renders it excellent for cultivation. Thus, by skilfully directed jets of water, the Californian miners wash down high banks of sand or gravel in order to collect the particles of gold carried along in the stream, and in the same way in the Pyrenees numbers of rocky cliffs might be broken up into debris and be conveyed into "warping" channels so as to spread them in the form of an alluvium, no less precious than gold, over the barren sands of the Landes. This idea of Duponchel the engineer is certainly no mere fancy. M. Bazalgette has lately proved how far the attempt might be made to bring into being, as if by enchantment, tracts of fertile meadows on the unalloyed sands of the sea-shore, when watered by sewage brought from London more than 40 miles distant. Liebig, the chemist, asserts that the naked sea-shore is incapable of producing a single blade of grass, and yet for all that it is now yielding every year six or seven cuttings of nutritive rye-grass.*

* M. Réclus is evidently confusing the sewage farm in the Barking marshes with the hitherto abortive plan of reclaiming by means of the London sewage the sands on the Essex coast.—(Tr.)

CHAPTER XXII.

THE CULTURE OF MARSHES.—DRAINAGE OF THE GROUND IN THE COUNTRY AND TOWNS.

By means of irrigation, the agriculturist succeeds in reclaiming arid tracts of land, such as the sands of the Landes, the clays of the marshes, and rocky cliffs; by means of drainage, he adapts to his use flooded lands which had never produced anything, and converts it into the most fertile soil, and the name of "nursery-gardener" is now applied to those gardeners who, in the vicinity of our large towns, are able to make the largest quantity of vegetable substance spring from the smallest area of ground. Every advance which mankind has made either in Italy, the plains of France and Germany, on the saturated soil of Batavia, or in Great Britain, would have been impossible but for the draining and sanitary improvement of the ground; every spot where civilization has partially retrograded, as may be seen round Carthage, Syracuse, and Rome, is marked by fresh encroachments made by marshes once reclaimed. At the present time, when the work of colonization is carried out on so large a scale, the principal work of the pioneers in Mitidja, on the shores of the Mississippi, on the coasts of Columbia, the Guianas, and Brazil, in the Sunda Isles, and on the coast of Africa, is to consolidate the soil and to purify the air, so as to add a fresh domain to those which mankind has already fully appropriated. This is a work which costs a considerable number of lives every year: in many a plain now rich with harvests the number of peaceful agriculturists who have perished in their toil is greater than that of the soldiers who have fallen on fields of carnage, such as Leipzig or Sadowa; but everything gives way before patience, and sooner or later, thanks to the increase of the human race, to the progress of its industry, and to the combination of its forces, the marshy banks of the Amazon, the lagoons of Paraguay, the wet districts of Lake Tchad, and the Sunderbunds of the Ganges and Bramahpootra will ultimately become healthy countries. In all climates alike this work of improving the earth is being carried on. In Norway, where the area of arable land was in

1866 only 1000 square miles, the agriculturists are now reclaiming every year 40 square miles of the marshes and fjords.*

At the present time the plan proposed by scientific men is nothing less than that of establishing below the surface of the ground a circulatory movement of waters, analogous to that which is naturally taking place in the air and on the surface of the earth by means of clouds and rivers. The water rises from the sea in the form of vapour, and floating through space is precipitated in the shape of rain and returns towards the Ocean through streams and rivers; but this water which is flowing down towards the great reservoir of the sea, is on its way appropriated by the agriculturist, who divides it into channels and then into small streamlets for irrigation, and these are distributed not only on low-lying fields, but also on the sides of hills and mountains and even over high plateaux. The water, thus being divided into innumerable branches, sinks into the soil over the whole surface of the district, where, like a second rain, it refreshes and nourishes the roots of the plants. Its work of usefulness is then terminated, for if it remain for any length of time in the ground its action will become fatal to vegetation; it will drown and rot the small rootlets and close up the pores through which the outer air penetrates.

Thus, irrigation may be fatal where the subsoil does not possess, like the surface, a perfect system of channels relieving the ground of any superabundant moisture. The water filters drop by drop into the small drainage pipes, then the different streamlets unite into one larger drain, and gradually increasing in its course, the invisible rivulet flows from pipe to pipe, and discharges either into a river or into the sea. Such is the immense work of subterranean drainage which agriculturists are now undertaking in a multitude of localities; and the result is that all the hydrological and climatic conditions of the soil are slowly but surely modified. The damp countries of civilized Europe, especially Great Britain, are the places where the drainage of land is carried on to the greatest extent; in England alone the length of all the drain-pipes placed end to end must be estimated at not less than 6,200,000 miles or 250 times the circumference of the earth. Unfortunately the conflict of private interests and the lack of enterprise and wide views in most of the proprietors of the soil, have prevented this work being accomplished according to any general plan; each one works at it in his own field without troubling himself about his neighbour, and too often these partial

* Frisch, *Mittheilungen von Petermann*, xi. 1866.

systems of drainage result in swelling the streams and changing the lands situated below them into marshes. Sooner or later the immense undertaking involved in the aëration and drainage of the soil will have to be systematically recommenced so as to be adapted to the whole area of every fluviatile basin. Then and then only shall we be able to compare the artificial system of drainage with the natural network of running streams; the whole of the partial circulation established in each country by human labour will correspond with the general circulation produced in the air and on the ground by the rotation of the globe.

Large towns especially are the chief places where subterranean drainage has in our time begun to be carried on in the most systematic manner. It is well known that rivers and streams of pure water are used in our towns as receptacles for all kinds of filth. If, for instance, we take London, that great city consisting of more than three hundred thousand houses, and containing more than three millions of inhabitants, which is connected by endless streets to numbers of rising suburban towns, which seem to increase under your very view, and if we pass down the marshy banks of the wide Thames, which flows between such immense swarms of humanity, we shall see how that nation of the world, who knows best how to appreciate nature, also pollutes her. At the ebb of the tide when the current of the river, with its slow and dark stream, flows on towards the sea, beds of semi-liquid mud filled with putrifying rubbish are gradually laid bare, emitting into the air their nauseous exhalations: inspired by a sentiment of instinctive disgust, one is almost surprised to see the blue sky and the clouds reflected in these beds of moist filth. At the flow of the tide when the body of water, being arrested in its progress, gradually rises and ascends the Thames, the islands of mud cease to be visible, but most of the unclean rubbish which has been borne down by the ebb is again carried up by the flow of the tide; a kind of to and fro motion is constantly shifting these impurities up and down stream under the eyes and noses of the inhabitants.*

This is the mode in which the great river is polluted; † the rivulets and even the small streams which fall into the Thames, after having flowed through a portion of the province now become London, have

* See below, p. 242.

† The whole of the last paragraph was evidently written without any cognizance of the present system of London drainage. Although this system is as yet only partially completed, the state of things described by M. Réclus is now much modified.—(Tr.)

long ago disappeared under the streets and the houses, and are become nothing but sewers. That which has taken place in the vast English city has been equally the case in all the spots where men are most densely accumulated; Paris has thus changed the Biévre, which flows down to it so pure from the hills round Versailles, into a mere ditch of liquid filth; sometimes, when the water is low in the Seine, a solid mass of impurity may be extracted from the liquid, equal to nearly a fortieth part of the whole flow of the river. Everywhere we find that the groups of men, whom rivers have drawn to their banks, have commenced by polluting the water, and have often rendered it unfit for drinking purposes or even altogether injurious to health. The forcible and gross names, which the inhabitants of the South of France have given to most of the rivulets which flow through their great towns, give us some indication of the hideous state of uncleanliness which these streams have now attained.

Having thus deprived themselves of the drinking water which nature had placed at their disposal, although the quantity would, indeed, in most cases have been insufficient, the inhabitants of many towns have been compelled to replace them by spring-water or streams artificially conveyed to them at great expense. This is one of the principal problems which we have to resolve in respect to the well-being of the rapidly increasing populations which are crowded in our great cities. In former days mighty Rome, who made the conquered nations of the whole earth work in her behalf, diverted, by means of aqueducts, the water running from all the adjacent mountains and made it flow down into her public squares, where it jetted out in abundant streams from a multitude of fountains, and was collected in wide basins. At the present day, there are very few modern towns which receive a quantity of water so considerable, comparatively speaking, as that which flowed into ancient Rome; most young and rising cities, growing as it were at random, have not, in their foolishness, as yet understood what are their most imperious requirements, and are still deficient in the necessary supply of water. Their attention is, however, being more and more awakened as to this point, and the nineteenth century will not close before most of our large towns are abundantly provided with all the water necessary both for drinking purposes and for cleanliness. The hydraulic works of this description which have been already undertaken round Marseilles, Paris, Glasgow, New York, and Chicago, exceed all that the Romans have done in this respect, not by their beauty as works of art, but by the length and capacity of the aqueducts, and especially

by the skill with which the engineers have succeeded in overcoming natural obstacles. New York is built upon an island. No matter! Pure water is made to flow into it from the mainland passing over the Hudson through a gigantic arched syphon; Chicago is built at the mouth of a marshy river and by the side of a lake, the water of which is constantly polluted by the ships anchored along its shores. No matter! Chicago draws its water at a point a mile and a half from the shore by means of a large tunnel dug under the bed of Lake Michigan; it requires a submarine stream for its daily drinking-water!

With regard to the discharge of sewage water—a point scarcely if at all less requisite than the supply of pure water—London, the greatest city in the world, is the one which has become the model city in this respect. The total length of its sewers is 80 miles, and they have been built large enough to carry away from the town 2300 millions of cubic yards of water and filth every 24 hours, that is about 28,000 cubic yards a second, a larger body of water than the Mississippi pours down on an average towards the Gulf of Mexico. But the effect of these subterranean rivers is not merely to draw off the sewage water, which until lately tainted the Thames; they will soon, by means of irrigation, spread over more than 148,000 acres, at a distance of 40 miles from London, and will produce grass enough to supply the requirements of 100,000 milch-cows, many more indeed than is necessary to provide butter and milk for the whole of the immense city. "Thus," states the report of the Board of Health, "completing the great circle of life, death, and reproduction." Like some prodigious animated being, London is incessantly absorbing water by its aqueducts, and food and commodities by its railways; and the refuse, which it rejects and carries far away through its sewers, is made available for reconstituting the nourishment necessary for its enormous appetite.

CHAPTER XXIII.

THE DRAINING OF LAKES AND INLETS OF THE SEA.—THE LAKE COPAIS, THE LAKE OF FUCINO, THE SEA OF HAARLEM, THE ZUYDER ZEE.—POLDERS.—THE PURIFICATION OF SALINE MARSHES.

Emboldened by the reclamation of marshy lands, agriculture wished for more; its next requirement was to take possession of the beds of lakes, and of low grounds occasionally covered by the sea-water. From the earliest antiquity great works of this kind have been undertaken; twenty-two centuries ago, in the time of Alexander the Great, Krates the engineer devoted himself to the task of entirely emptying the lake of Copais, in Bœotia. During a long series of dry years this basin was often reduced to a few pools of marshy water, and tiny rivulets crept over the plain between the reeds and rushes; but, on the contrary, in rainy seasons it was a fine lake with an area of several millions of acres, and was constantly swelled by the torrents which came down from Helicon and the other mountains in the vicinity. The water was separated from the sea by a wide rampart of calcareous rocks, and found no means of outlet except by certain deep fissures or *katarothra*. Krates straightened these so as to facilitate the flow of the water; but since this epoch they have become again obstructed, and the projects which have been formed in later days for restoring the work of the ancient Greeks have been all in vain.

Modern engineering skill has been more fortunate on the soil of Italy in resuming and finishing a great work of drainage which the Romans were not able to bring to a happy conclusion. The lake of Fucino, situated fifty miles to the east of Rome, near the towns of Avezzano and Celano, occupies the centre of a circular range of hills in the Apennines, formed like a crater, the slopes of which are covered with dwellings and cultivated fields. Sometimes floods inundated all the country round, and destroyed the crops; and afterwards, when the water ran off, the air was filled with poisonous miasmas; the difference between the levels shown during high floods and at low water was not less than thirty-nine feet. During

the reign of Claudius, thirty thousand slaves worked for eleven years in digging out a channel 6151 feet in length across Monte

Fig 103—The Lake Copais

Salviano, in order to draw off the largest portion of the water into the Liris, and thence into the sea It was fully believed that the work had been happily achieved so as to last for centuries, like the tunnel, about one-third the above-named length, which had been dug more than four hundred years before from the lake Albano, near Rome. All that now remained to be done was to open the flood-gates The emperor, vain as cruel, had prepared a splendid *fête* upon the lake; nineteen thousand gladiators, embarked in two opposing fleets, were to figure before him in order to celebrate the inauguration of the canal. The slaughter took place, but when the order was given to empty the lake, the water, mixed as it was with blood, refused to flow out. Narcissus and some other courtiers, enriched at the expense of the public treasury, had doubtless kept back the money which was necessary to complete the works of consolida-

tion. Later, at different periods, the canal was cleaned out, and rendered a certain amount of service at times. At last, in 1854, the works were energetically resumed, the outlet was enlarged, and a mass of water amounting to more than a thousand millions of cubic yards, which the lake contained above the level of the tunnel, was emptied out, the marsh fevers ceased their ravages, and cultivation gradually advanced towards the centre of the former lake-basin.

Among the great modern undertakings in the way of drainage, the most important, on account of the obstacles which had to be overcome, and also of the prospect which has been derived from it, is, however, that which has entirely recovered and added to the mainland the whole bed of the lake known by the name of the Sea of Haarlem. This lake, as it appears, began to form in the 13th century, and since that date continued constantly to increase at the expense of the cultivated land and villages surrounding it. In the 16th century it had acquired the dimensions of a sea, and naval combats were fought on its waters, between the Dutch and the Spaniards. Every great tempest added to its extent, and during the winter of 1836 a violent west wind caused it to reach the very gates of Amsterdam. The banks round it, which were kept up at a great expense, were of no avail in holding back the water which rose incessantly. Then it was that, looking forward to imminent danger caused by the encroachments of the Sea of Haarlem, the resolution was come to to endeavour to drain it dry. It was thirteen miles long and six miles broad, with an average depth of thirteen feet, and contained a body of water estimated at 950 millions of cubic yards. In addition to this, it was also necessary to reckon on the water resulting from infiltration and from rainfall, which would make its way into the lake during the time whilst the drainage operations lasted; this was estimated at about 260 millions of cubic yards of water. In 1852 this immense work was completed, and three enormous steam-engines, pumping together at each stroke of the piston as much as 260 cubic yards of water, had discharged the whole of the Sea of Haarlem into the Ocean. At the present time the only work the steam-engines have to do is to clear the former basin of the lake from the water accruing by infiltration and rainfall, or, during the dry seasons, to furnish the water necessary for irrigation. In fact, the soil at the bed of the lake, having been for so long a time deprived both of air and sun, could only be gradually changed into arable ground capable of absorbing easily the rain

water, and giving it back in the shape of vapour. It was necessary, says an author, to bring machinery to its aid, in order "to complete its education."* The clayey and peaty bed of the lake, which, since the process of emptying out and draining had sunk about eleven inches, is now changed into fine cultivated lands, and the public wealth of Holland has been thereby increased to a very great extent. The emptying and drainage works cost £1,320,000; but the "*polders*," the appearance of which, it must be confessed, is singularly wanting in the picturesque, already represent a value of over £6,000,000.

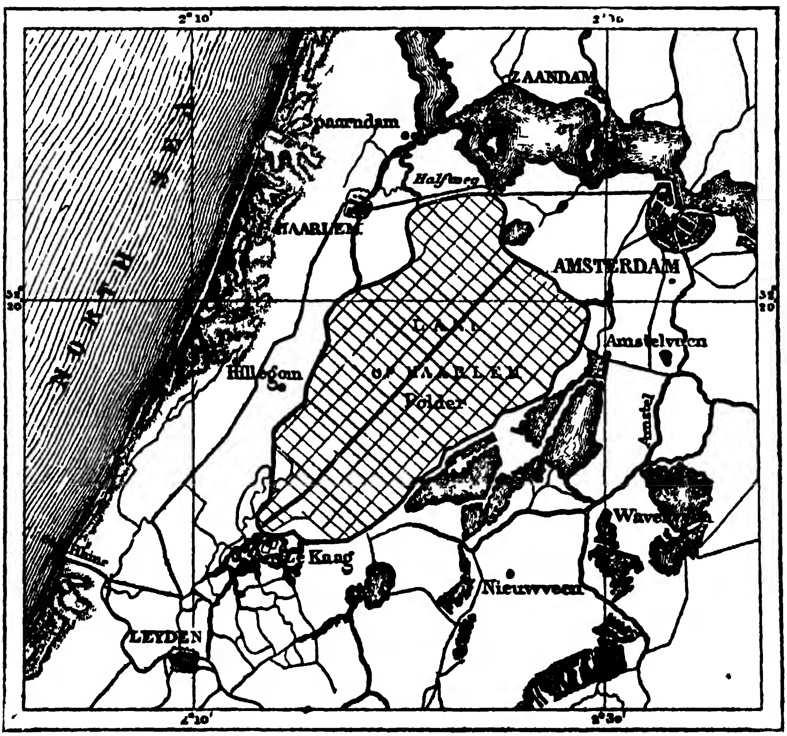


Fig. 194.—The "Polders" of Haarlem.

Is not, however, the greater part of Holland nothing but a vast sea of Haarlem, which the energetic and persevering people of the Low Countries, by their labour, continued from age to age, have

* E. Marzy, *l'Hydraulique*, p. 235.

succeeded at last in laying dry? The very sight of the level soil, every clod of which has been so often turned over and over, and of the defensive dikes which divide the country into an infinite number of parcels, shows how an entire nation—in conflict with nature, and acting somewhat in the mode of a geological force, never ceasing for generations in its endeavours towards this great work—has succeeded in reconquering the soil of the country, and rendering it fit for cultivation. It is probable that sooner or later the vast gulf of the Zuyder Zee will be also recovered from the Ocean. This work would certainly have been commenced, but for the fact that the greatest part of the bed of this gulf consists of fine sand, which is difficult to bring into cultivation.

The ground reclaimed centuries back, either from the sea or from marshes, does not present any geometrical regularity in the network of its canals and draining channels. In former times the engineers were not so bold as they are in the present day, and in the formation of their canals utilized all the small natural watercourses and passed round all the scarcely dried rising grounds in such a way, that their ditches assume a winding and sometimes wavy line. As a whole, this network of intersecting liquid veins presents a form somewhat analogous to the great and small vessels which follow out their ramifications in organized bodies. The land more recently reclaimed does not show in its system of drainage these meandering and picturesque lines; it is cut across by its canals with a mathematical regularity. At regular intervals rectilinear and parallel canals have been dug, which extend from one end to the other of the whole space enclosed by the dikes. These canals are crossed at right angles by main arteries of the same width, and thus the whole country is divided into great parallelograms, which are again subdivided into small parcels of land by narrower canals and ditches, both equally rectilinear; the farmer is obliged to use boats either to visit his farm, to carry his manure, or load back his crops. All round this vast chess-board of cultivated ground extends the canal which surrounds it and receives the drainage water of the *polder*, being protected by strongly made dikes against inundations coming both from without and within. At one time it was the wind which was employed to raise the surplus water of the *polder*, and discharge it directly or by means of canals into some one of the rivers of Holland. The drainage pumps were worked by those picturesque windmills which the Dutch painters exhibit to us in all their landscapes; but at the present time the larger *polders*, for which it is

indispensable to assure a constant and regular flow of drainage, are provided with steam-engines which incessantly pour water into the outside canal.

When the lakes which have to be dried up are so deep that it is impossible to reclaim them for cultivation by mere ditches and canals, the only course left is either to empty them boldly as the Sea of Haarlem was emptied, or else it is necessary to work for centuries in elevating above the surface of the water certain small islets which will ultimately be joined one to another. The brave agriculturists of the Low Countries, feeling that the lapse of ages made them one with their descendants, did not shrink from undertaking this task, which would some day be completed by their grandchildren. In the first place, they made dikes round the banks of the lowlands, which they could drain with comparative ease, and afterwards, when the alluvium had caused a bed of mud to show itself above the water, they lost no time in taking possession of it, and in raising and draining it, giving to it an elongated form which would subsequently facilitate the labour of digging canals when the pool was changed into a *polder*. Several generations beforehand they foresaw what would be the general arrangement of the land, which at present lies under water, and every shovel-full of mud that was brought up from the bed of the pool, every pile that was driven down into the ooze, was made to take its part in the continuation of the work. We are enabled to form some idea of the wonderful patience and methodical spirit with which the farmers of the Netherlands carry on their labours if we travel over the Zuyder *polders*, and numerous other districts which are now fields, although still in part consisting of lakes. The houses in the villages are built in a long circular street on the top of the dikes which surround the lake, and the fields, divided by canals, spread out like the sticks of a fan round the centre of a sheet of water. According, however, to the outline of the lacustrine and marshy spots which are subjected to the operation of drainage, the *polders* assume other shapes of equal regularity; they form squares, stars, and concentric polygons. If seen from a balloon, some parts of Holland, with the innumerable grey lines of their ditches and canals, would recall vaguely to the mind's eye the surface of certain chemical bodies crystallized in radiating or parallel needles. The astonishing regularity of the landscape is undisturbed, save by the masses of buildings in the large towns, the parks which surround them, and the roads and railways crossing the canals in an oblique direction as they emerge from the cities.

The Dutch are so much accustomed to recover land by means of canalization, that they often go to work in the same way in cases

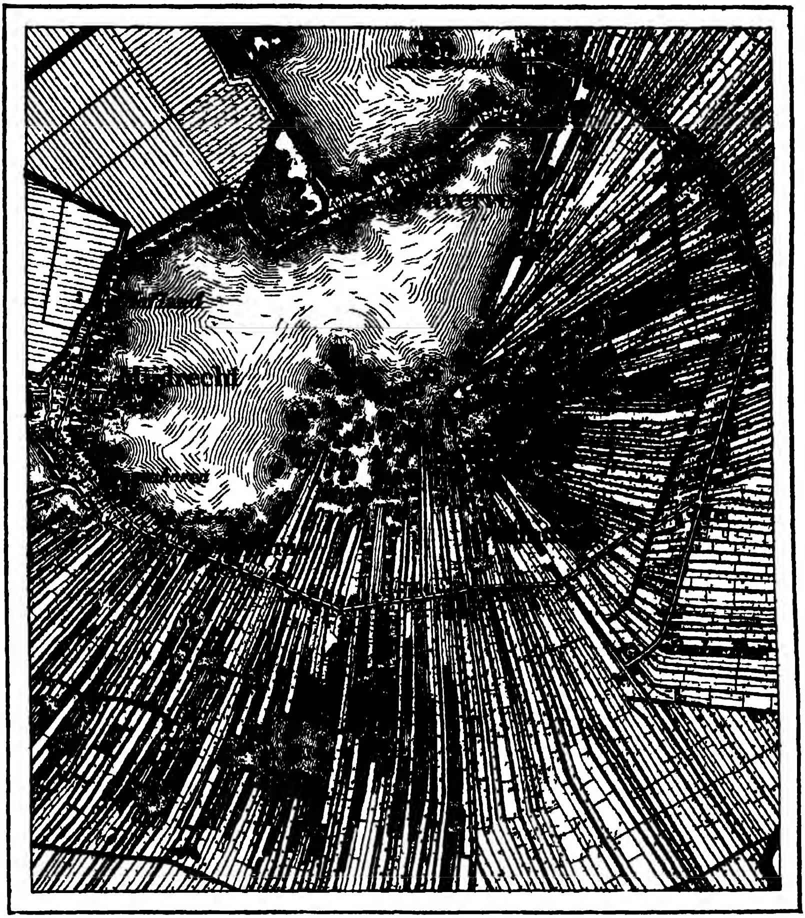


Fig 195.—The Zuyder Polder

where the ground might have been brought under cultivation by other processes; and even in the tropical climate of Java, they have transformed the environs of their cities into small editions of Holland. On the east of the Low Countries, the inhabitants of Friesland, Ditmarsh, and Schleswig have had to come in conflict with the same difficulties, and, like the Dutch, have been able to triumph over them, and to convert into *polders* vast tracts of inundated ground. On the

east coast of England, the shores of Suffolk and of Norfolk, the estuaries of the Wash and the Humber are bordered by fens of very great fertility; and the encroachments of agriculture on the Ocean-domain take place in these districts on a very extensive scale. In the same way, in Belgian and French Flanders, in the neighbourhood of Ostend, Dunkirk, and Calais, the *watteringhes* have been reclaimed from the North Sea. Near Etaples, the inland sea of Ponthieu or Marquenterre has been changed into fine cultivated fields; and between the mouths of the Loire and the Charente the marsh-lands are everywhere protected by dikes and intersected by ditches which are crossed by the country-people, both male and female, by means of their long leaping-poles. To the south of the Gironde there are also some "small imitations of Flanders," and in the Landes the Lake of Orx has been recently drained by the same kind of operation as that adopted in the Sea of Haarlem.

In Holland and all the other countries bordering on the North Sea it is only necessary to throw up dikes round, and to drain the marshy tracts by the sea-shore, and they will be converted into fertile fields, fit after a few years for any crops which the climate allows. On the coasts of the Mediterranean, Caspian, and other seas, another course has to be adopted. In these districts the tracts of ground which have formerly been inundated by salt-water always remain more or less saturated with salt and are unfitted for any permanent course of cultivation. Thus, instead of turning them into cultivated fields, it is found better worth while in many spots to utilize them as salt-marshes. The salt-water, conducted from one pond to another, evaporates in the sun, and ultimately leaves on the bed of the last compartment a thin layer of salt, which the labourers collect and pile up in great pyramids on the edge of the roads. This manufacture assumes its chief importance on the shores of the western Mediterranean; certain salt-works on the sea-shore there produce from ten to twenty thousand tons every year.

What is the cause which produces the contrast between the natural fertility of the *polders* of Holland and the sterility of the ground recovered from the sea on the Mediterranean coasts? The cause must first and foremost be sought for in the greater or less supply of fresh water which washes the soil. On the shores of the North Sea the air is naturally moist, and the quantity of rain-water which is showered down upon the country is very considerable. The porous earth is constantly washed by the rain, and all the soil on the surface is gradually carried away, so that almost immediately they are

surrounded by dikes the cultivation of the *polders* may be commenced. It must be confessed that, on the shores of the Mediterranean, the

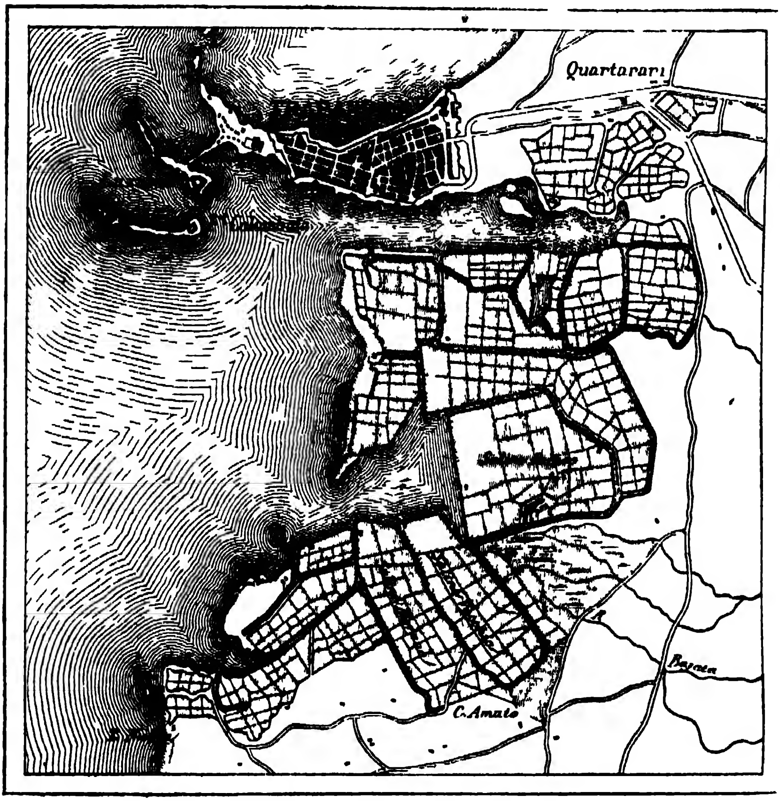


Fig 196 — The Salt-works of Trapani.

saline portions of the ground are likewise dissolved and carried into the subsoil; but in consequence of evaporation, which is very active in this climate, the water from the bottom ascends gradually through the porous earth together with the salt which it holds in solution, and then evaporates, leaving on the surface a crust more or less thick of saline matter. A reciprocating motion is thus established between the surface and the deeper strata of the ground; the rain causes the salt to descend and evaporation causes it to rise up again, whilst the sea-breezes add an additional thin layer of salt to that which already exists on the soil. Pools of almost fresh water and a saline efflor-

escence cover in turns the surface of the ground; the plants which the labourer would fain endeavour to cultivate are either drowned by water or else burnt up by salt.

Fortunately, the knowledge of the evil has led to the discovery of the remedy. It is found that rain carries the saline matter down into the subsoil, and therefore that great temporary inundations would bring about this result with a much greater degree of certainty. After having established at a suitable depth a complete system of drainage, it is only necessary to turn for some time a branch of a stream over the land to be drained; the salt in the upper stratum will immediately be dissolved and carried down into the subterranean conduits, being ultimately removed by this powerful lixiviation into an external basin where the emptying pumps are worked. The frequent application of this process of washing succeeds at last in cleansing from all saline matter the land that was most saturated with it; and agriculture thus gains a new and fertile field for its operations. Moreover, this means of reclaiming low, salt tracts on the shores of the Mediterranean is no longer a matter of mere speculation, as it has already been put in practice. Not far from Saint-Gilles, on the smaller branch of the Rhone, certain tracts have been purified from the salt which they contained and converted into corn-fields. More recently, immense tracts of land near Frontignan, once perfectly useless, have been gradually purified by the little stream, Roubine de la Vie, which supplies pure water by a lateral cutting, and then lower down in its course receives the drainage-water charged with saline matter. According to M. Dupouchel, the inventor of this system of purifying the soil, it would be possible to deal thus with a great part of the south coast of France, and to create a complete border of magnificent *polders*, covering a surface of more than 250,000 acres, and representing an agricultural value of from 20 to 30 millions of pounds.* And what even would such a reclamation as this be, when compared with those which may some day be made in all the countries which border on the sea and on salt lakes?

* *Annales des Ponts et Chaussées*, ii. 1864.

CHAPTER XXIV.

DIKES ON THE SEA-SHORE.—POINTS OF DEFENCE.—POINTE-DE-GRAVE.

Throughout the whole region of *polders* scattered along the coasts of the Ocean, the immense labours undertaken with a view of draining dry certain tracts of land must necessarily be completed by a system of marine fortifications, for it is necessary to defend at any cost against the force of the waves and the shock of the tempest, the cultivated land which has been with so much difficulty reclaimed. The whole of the sea-boundary of Zealand, Holland, Friesland, and the other "low countries" on the coast of the North Sea, is bordered by a continuous rampart of dikes, about 25 to 35 feet high, and 150 to 300 feet broad at their base. All these embankments are constructed with the utmost care, with their longer slope, on which the waves have to break, towards the sea; the bank itself is armed against the surf by a trellis-work of posts, fascines, and even by a woven texture of straw over which the waves glide, being changed into foam. On the land side the dike has a steeper slope and is bordered by a small drainage ditch, in which is collected the water which soaks through the earth or is thrown by tempests over the top of the embankment. Should

Fig. 197.—Profile of a Sea-Dike in Friesland.

the sea, when it is very rough, destroy one of these ramparts, a portion of the *polders* is inundated; but at a certain distance another dike rises, and beyond this, others which keep back the flood-waters. During the continuous labour of more than a thousand years the country people, ever on the watch to snatch a slice of land from the ocean, have never ceased constructing embankments round every reef of mud left bare by the sea-water, and the defensive ramparts

are thus connected all round the outside of the district; in some spots where the deposit of the ooze from the sea takes place rapidly, the districts of the interior are separated from the shore by a quadruple or quintuple girdle of embankments. It must be confessed that, on the occasion of fearful storms, the recollection of which ever dwells in the memory of the inhabitants,* the sea has again taken possession of wide tracts of land, in exchange for those which man has snatched from its domain; but at the present time the Dutch engineers, the most experienced and most skilful in these operations, are making regular encroachments on the seas surrounding them. It has been calculated that, on the average, the area of the Low Countries increases at the rate of seven acres a day, or 2470 acres a year; † this is somewhat more than a four-thousandth part of the whole territory.

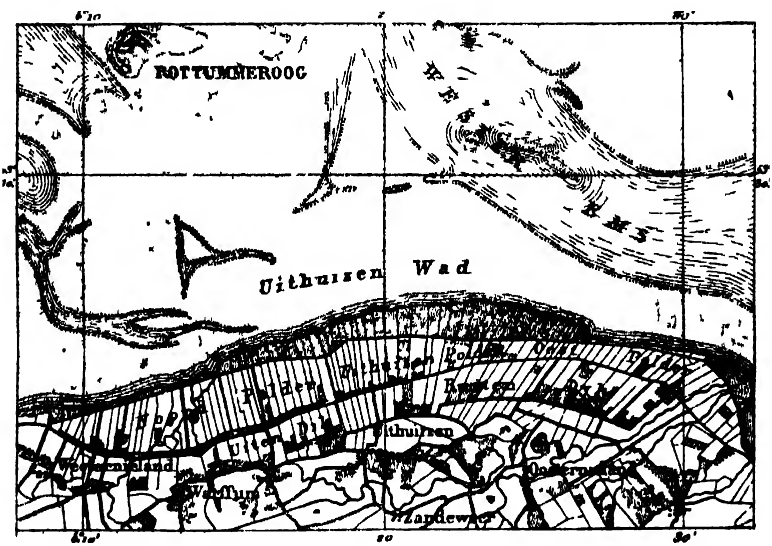


Fig 193—The Dikes of Uithuizen

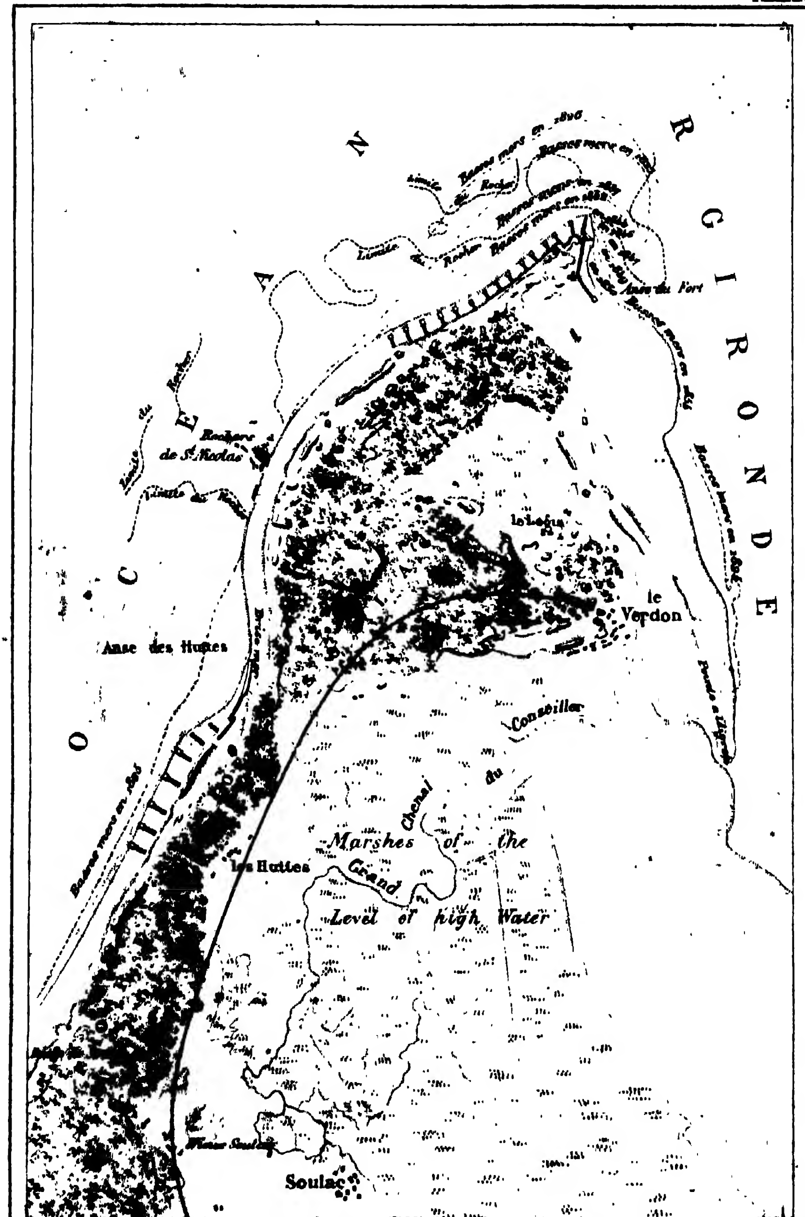
The length of the dikes placed end to end would extend to several thousands of miles; they much exceed the embankments along the borders of the Mississippi and its tributaries.‡

Those spots where the currents, waves, and winds blowing from the sea, all work together to break through the shore-line, are

* See Chap. XIX. p. 161.

† E. de Laveleye, *Revue des Deux Mondes*, April 1, 1864.

‡ See in *The Earth* the section entitled, *Rivers*.



Engraved by Erhard

Furlongs 4 3 2 1 0 ½ 1 Mile

the places where man is compelled to show proof of the greatest perseverance and the most inventive genius in his strife with the elements. In the Isle of Sylt, on the coast of Schleswig, the idea was formed of making the sea itself a joint-worker in the construction of the dikes which were to stay its progress. All along the sea-beach palisades were set up in two parallel rows, about ten or twelve yards distant from each other. During a tempest, the waves charged with sand dash over the fascines, and let fall among the branches the sand and shingle that they carry; the latter is heaped up between the two lines of palisades, and soon a long artificial *dune* is raised along the edge of the sea, affording protection to the land inside. Means of this kind cannot, however, be successfully made use of on every coast, and especially on various points of the shores of Holland, which seem to sink down below the sea level like a leaky ship. The town of Westkapelle, in Zealand, was devastated by the waves which opened a wide inlet through the rampart of *dunes* on the shore. The houses were rebuilt further inland, under the protection of an enormous dike which closes the gap between the sand-heaps; but this embankment has entailed such an enormous amount of labour in its maintenance and repair, that a bulwark of solid copper might have been erected at less expense.* In a similar way, owing to a large opening being forced between the *dunes* on the shore, the Isthmus of Perren, situated on the western coast of the peninsula of Holland, was threatened with being swept away; in this case, Amsterdam and all the shores of the Zuyderzee would have been left without protection against the waves of the sea. But by means of various works, dikes and stake-barriers, the inhabitants ultimately succeeded in giving solidity to the shore. At the present day the inhabitants of this part of Holland have no longer anything to fear from the inroads of the sea.

In France, Pointe-de-Grave, at the mouth of the Gironde, is one of those spots which may most aptly be brought forward as an instance of the violence of the sea, and as a locality where man has to strive his hardest with the breakers. It is known exactly how far the sea-beach has shifted its position since the year 1818; at this date Pointe-de-Grave extended into the Gulf of Cordouan, 2400 feet to the north-west beyond its present position. Between 1818 and 1830 it receded 600 feet, or 50 feet each year. From 1830 to 1842 it lost annually nearly 120 feet. Between 1842 and 1846, when the engineers were at last engaged in their conflict with the sea, the

* Smallegange, *Nautical Almanack*, Nov. 1863.

waves advanced 630 feet in their triumphant march, that is more

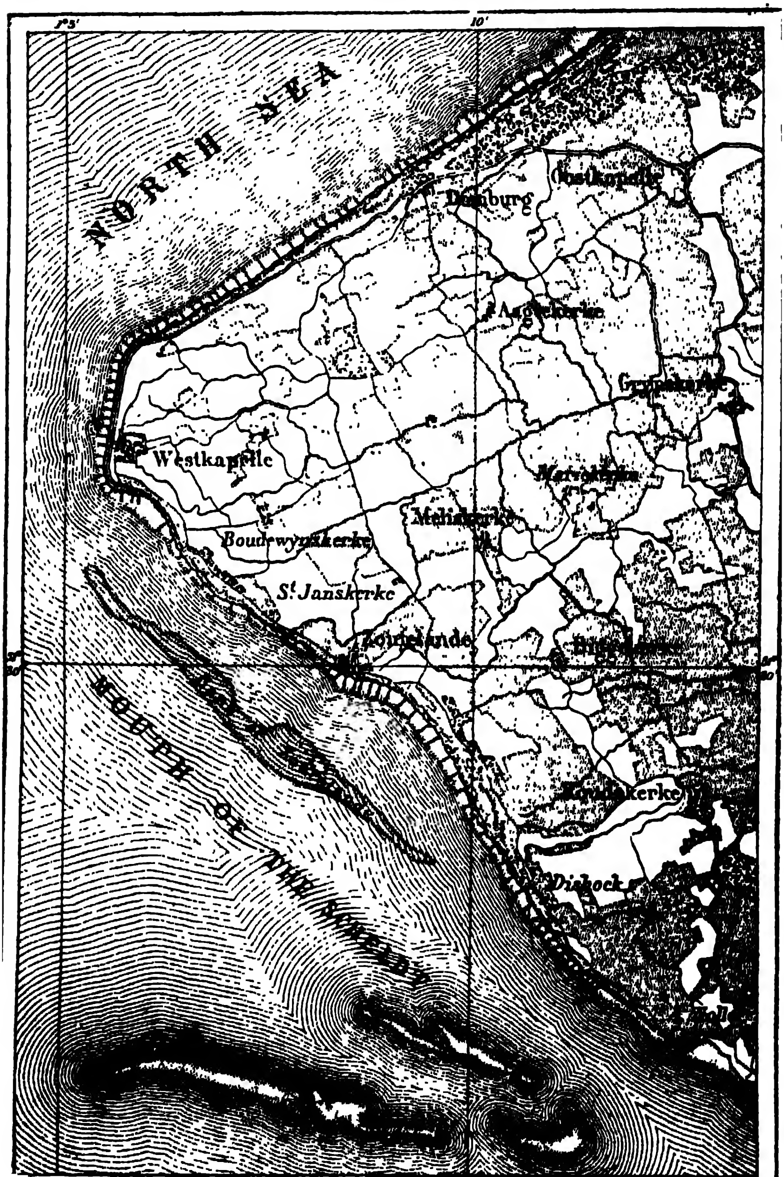


Fig. 190.—The Embankments of Westkapelle.

than 150 feet in one single year. Now, the sounding-line shows a

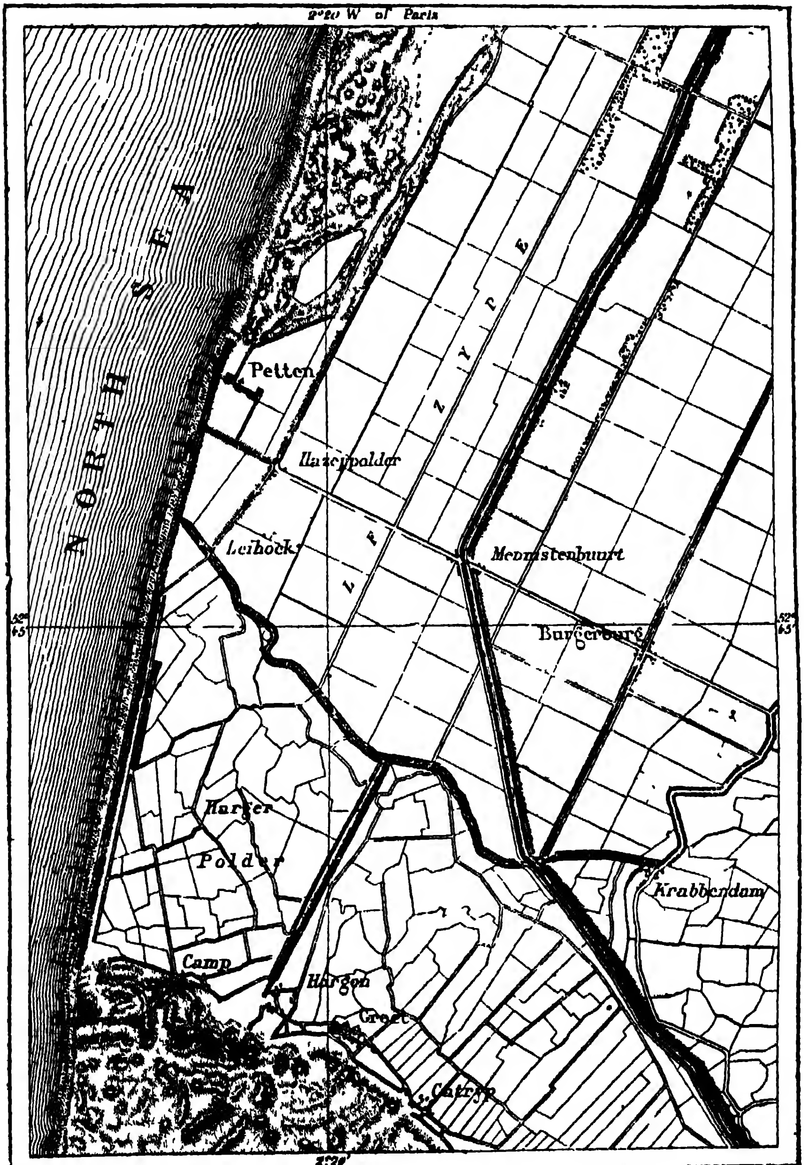


Fig. 200.—The Embankments of Petten.

depth of more than five fathoms at a point where the outline of the shore might once be seen. It has been found necessary to pull down, and rebuild further inland, all the buildings which once stood at the extremity of the point. The ancient fort which defended the entrance of the Gironde has been demolished by the waves, and during the low equinoctial tides cannons may still be seen shining in the wet sand. In 1846, the width of the strait which separates Cordouan from the peninsula of Bas-Medoc had increased exactly one-tenth in the period of 28 years.

Whilst the sea was thus eating away the extremity of the peninsula, at the same time it was endeavouring to pierce into its base. At the narrowest point of the isthmus which joins the *dunes* of Grave to Medoc, the waves worked energetically in scooping out a wide bay known under the name of the bay of Huttes. From 1825 to 1854 the sea-shore receded 1140 feet. During the period of low tides the isthmus of Huttes, which extends between the ocean and the salt-marshes of Verdon, was still 1320 feet in breadth; but at the time of flood-tide this breadth was reduced to 960 feet, and when the waves are lashed into fury by a storm, they throw their foam to the very summit of the sand-banks on the narrow isthmus. Another five and twenty years of an advance as rapid as this, and the Atlantic will succeed in breaking through the fragile bank of sand which is opposed to it by the main-land, and will overflow into the marshes, converting into an island the present peninsula of Grave. The Gironde will join the sea by a second mouth, and the present generation may contemplate geological phenomena similar to those which took place when the island of Cordouan was detached from the main-land and gradually changed into a shoal. It was necessary to prevent this not only as it would have caused the ruin of all the property on the peninsula; but also as a matter still much more important, it was necessary to preserve for ships the precarious shelter afforded to them by the roadstead of Verdon, which is already too much exposed to the violence of the west winds in consequence of the constant erosion of Pointe-de-Grave. It was therefore with good reason that the resolution was adopted of entering into a contest with the ocean, and to arm the peninsula by means of bulwarks, against its assaults.

In order to protect the shore of the gulf, 13 parallel jetties from 500 to 600 feet long were constructed. These jetties were composed of stiff clay faced with stones firmly fixed, and were defended against the onset of the waves by fascines and piles; they thus offered resist-

ance both by their elasticity and the cohesion of all their parts. Nevertheless all those jetties were not strong enough to hold their own against the sea in stormy weather. First one gave way and then another; so it was resolved to construct a dike parallel to the shore of the bay of Huttes. During the course of the work the waves and storms often assailed the dike and broke through it in various spots; but the workmen, successfully fighting against the billows, were able to close up the breaches and to solidify those parts of the bulwark which had been broken down. In March, 1847, after five years spent in an incessantly renewed contest between man and nature, the dike, 3600 feet long, was at last finished and seemed to forbid the breakers any future approach to the *dunes*. The engineers had begun to congratulate themselves upon their work, and were fancying that they had vanquished the ocean, when a few weeks after the works were completely finished a terrible tempest from the south-west raged in the Gulf against the coast of Medoc; the last jetties of the bay were swept away like bits of straw, and the greatest part of the enormous dike was broken through, carried away, and annihilated by the all-powerful billows.

In order to check the inroads of the sea, they scarcely had time to construct at the inner curve of the shore of Huttes, a kind of pyramid composed of enormous blocks of concrete, each weighing several thousands of pounds. The gigantic steps of this embankment presented a firm resistance to the assaults of the waves, but as there was nothing else employed for the defence of the shore, the ocean soon showed threatening signs of turning it, and continuing beyond it its work of erosion. The shore of the bay of Huttes receded 80 feet, and two wells which had been dug, and lined with stone-work, in the sand of the *dunes* were laid bare to their very base and stood up like towers on the edge of the waves, presenting themselves as strange witnesses to show the inroads of the sea. The victory had been fought for by man at great cost, but the sea had remained the conqueror, and thousands of pounds lay peaceably buried under the waves.* At last it was resolved that, instead of building a mere water-wall, as had been already done, a regular breakwater should be raised to oppose the billows; this was to commence at the southern extremity of the bay and to stretch across to the north, joining the immovable rocks of Saint-Nicholas. In front of this rampart, cubic masses of concrete weighing several tons each were thrown down, so as to form a kind of gentle slope the length of which was equal to 10 times the height of the breakwater. Added to this, the

wicker-work embankments, being threatened by the incessant burrowing of the *Teredo*, were gradually replaced by strong dikes in stone-work. The ocean has not as yet broken through this last barrier, and hopes may be entertained that henceforth the same respect may be shown towards it. Nevertheless, the waves seem inveterate for the destruction of the obstacle which restrains them, and use in turn both force and stratagem to attain their end. They displace the blocks of concrete, they sweep away the sand, they make crevices in the masonry, and pushing forward in every direction their labours of sapping and mining, they untwist the fascines so carefully bound together, and sometimes leap over the construction itself, and boldly attack the shore beyond.

At Pointe-de-Grave the conflict between the sea and human power was scarcely less sharp. On that portion of the sea-coast which stretches away for a mile and three-quarters to the south of the cape, fourteen jetties, similar to those adopted in the bay of Huttes, were pushed out into the sea. At the point itself, instead of the jetty, there is substituted an embankment running out 400 feet, composed of natural and artificial blocks of stone dropped down into the water from trucks. The extremity of the embankment, which is under water, is prolonged for some distance by heaping up rocks which are dropped from small vessels when the weather is favourable. So great, however, is the violence of the waves, that these rocks, weighing on the average two tons each, are very frequently shifted by the meeting of the ebb and flow of the tide and are drifted out into the offing. When subjected to the shock of the waves, the embankment itself has sometimes cracked here and there across its whole width, and the workmen are from time to time obliged to reconstruct the slope, to fill up the cracks with stone-work, and to consolidate the blocks of stone whose equilibrium is threatened. Sometimes, also, the water hollows out caverns under the rocks at the base; it is then necessary to go down at low tide in order to stop up the excavations, to strengthen the approaches, and to prevent the advance of the enemy.

As if enraged at the insurmountable obstacle opposed to it by the powerful breakwaters at the point, the sea has spent its fury on the tongue of sand which extends behind the jetty. Attacking the bank on the rear, the waves incessantly increased the small bay of the Fort in the direction of the river, and between 1844 and 1854, whilst the sea-coast remained almost in a stationary condition, that which faced the Gironde receded 1600 feet, that is to say, 160 feet a year. A few years more, and the dwindled peninsula would have been com-

pletely broken through, the lighthouse and the other buildings would have been swept away, and the jetty, detached from the mainland, would become nothing more than a rock beaten by the waves. It was therefore necessary at any price to exclude the inroad of the sea by constructing at the angle of the Fort a breakwater similar to that which had been already built up in the bay of Huttes. A breakwater has since been erected in this spot, and at last a period of mere surveillance has succeeded to the contest of 20 years' standing between man and the ocean. The works, now happily completed, have ultimately contradicted the general superstition which attributed to the waves a force irresistible by man. The force of oceanic billows, like that of the aerial waves impelled by tempests, can be exactly estimated in tons or even in pounds; and in order to overcome their brute force, all man has to do is to oppose a superior resistance which can be measured by his calculations. It is, moreover, probable that a more profound knowledge of hydrological laws will some day enable him to utilize this very force which at the present time it is so difficult to resist; the ebb and flow of the tide, the waves of the tempest sometimes so terrible, will also find their work cut out for them, and their action when well directed will become an instrument in the hand of man.

CHAPTER XXV.

NATURAL AND ARTIFICIAL WAYS OF COMMUNICATION.—SEA-SHORES, DESERTS, AND SAVANNAHS.—RIVERS, CANALS, AND RAILWAYS.—BRIDGES AND VIADUCTS.—THE CUTTING THROUGH ISTHMUSES.—THE SUEZ CANAL.—THE ISTHMUSES OF CENTRAL AMERICA.

All the progress realized in the reclamation of the soil would have been impossible if nations had not been placed in mutual connection by means of frequent modes of communication; commodities are thus interchanged between various climates, ideas become a patrimony common to all, and the creative intelligence of workers has been enabled to develop and increase.

The earliest roads used by men for the purposes of travel and of conveying their produce were the natural routes afforded by the shores of the ocean, the deserts of sand and hard clay or rock, devoid of all vegetation, or by the level surface or gentle undulations of prairies and savannahs. Thanks to these ready-made ways of communication, nations separated by water, forests, and mountains have been enabled to make one another's acquaintance; but for all this, the mutual relations which they established remained very difficult to keep up. The sea-shores were intersected with quagmires and mouths of rivers both dangerous to cross; the deserts and savannahs are the abode of famine, and the traveller who ventures into them unprovided with food is certain to perish. After the lapse of thousands of years and thousands of ages, these natural routes still continue as dangerous as they were when they were ventured upon for the first time: nothing but his skill and industry has enabled man to create for himself safer and more commodious roads.

The invention of rafts and boats suggested other modes of communication between peoples; they could now avail themselves of the winding courses of rivers—those "moving roads." This was an immense progress made in favour of intercourse between nations, for every river with its tributaries tended to connect together all the countries comprised in its basin; this amount of progress was, however, in its turn surpassed. In the civilized countries of Europe, where man is gradu-

ally moulding Nature to his will, these uncertain watercourses, with their long windings, their dangerous rapids, their sudden floods, and their prolonged droughts, were no longer adapted either for merchants or travellers, both classes having become more and more particular in regard to speed and regularity. The inland navigation diminished, except on the mouths of rivers, which were also estuaries of the sea and had been converted by the skill of the engineer into regular canals having a considerable normal depth. This was the case as regards the Clyde, the bed of which a century ago was only three to six feet below the surface of the water; it is now dug out to a depth of 24 feet, so that large ships can easily ascend the river up to the quays of Glasgow. Inland, the natural waterways were

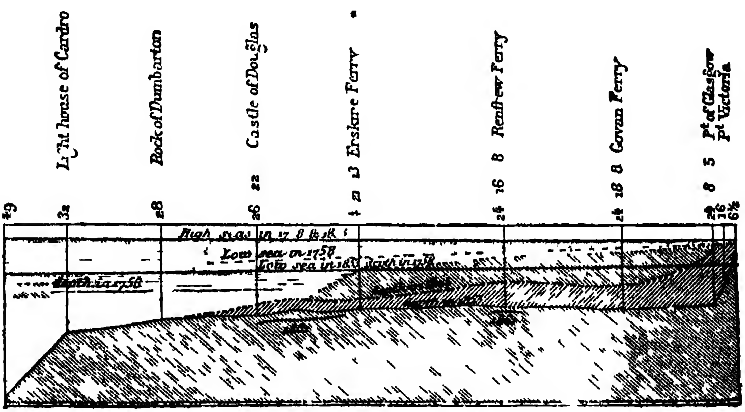


Fig. 201.—The progressive depths of the Clyde.

abandoned for artificial canals, the direction and depth of which man could regulate at his will; they were also to a great extent abandoned for carriage-roads constructed across the country in every direction and forming an immense network, and for railways, on which steam enabled a still greater speed to be obtained. Engineers have already made a demand for the suppression of our European rivers, such as the Loire, the Rhone, and the Rhine, as mediums of communication, and for the utilization of their waters for the irrigation of the land. "Rivers are roads for savages only," says M. Love, "and the only routes for transport recognized by civilized man are those which he has himself created from beginning to end."* And in fact, looking at the millions of money which have been expended

* *Discours de l'inauguration à la Société des Ingenieurs Civils*, 1868.

on the Loire since the commencement of the century, in repairing dikes, embankments, and houses, in flotillas of boats, and in reclaiming cultivated land, would not this cost have amply sufficed for the construction of a double line of railway along the whole extent of the valley, and for establishing a complete system of irrigation, which would have changed into a vast garden all those tracts of land which are now constantly threatened with some calamity by the rising waters.

Among all the great inventions of modern times, that of railways has indisputably contributed the most to give an impulse to travelling, to the diffusion of ideas, and to the general distribution of the riches of the earth. The services which railways have already rendered to mankind are incalculable; but nevertheless, the power of routine, the requirements of the public treasury, the impediments offered by custom-houses, the greedy system of monopoly and gain practised by the various companies, the absence of any large comprehensive views among the constructors of the network of lines, and the troubles and disasters of war, have singularly retarded the impulse which might have been given by the iron roads to the activity of nations. Railways are, however, as yet but very few in number in comparison with the area of the ground which they traverse; their total length is 99,360 miles, that is, about one mile only for a surface of 300 square miles. Not one of the great lines, which ought to cross various parts of the world from one sea to another, is as yet completed. The longest, which commences at Cadiz, and extends for a length of 3700 miles, passing through Madrid, Paris, Berlin, St. Petersburg, and Moscow, does not extend beyond Nijni-Novogorod, in the plains of Russia; twice this length remains to be accomplished before the rails reach the shores of the Sea of Okhotsk. The line crossing this, that which extends from the coasts of Pas-du-Calais towards Constantinople, has been arrested in its progress, for more than 10 years, by the course of the Danube. With regard to the New World, in 1869, it will possess a railway 3730 miles in length, which will cross the continent from the Atlantic to the Pacific, from Portland and New York to San Francisco, and will certainly become the principal commercial artery on the globe.*

The districts where the railway system is anything like complete are at present very few in number. The richest district in this respect is that of Lancashire, in which the first important railway—that from Manchester to Liverpool—was opened. This is where also Stephenson started his first locomotive. On this, the classic soil of manufac-

* This Railway is now in active operation. Tr.

tures, there may be reckoned at least one mile of railway for every four square miles of area. Also, the great facility of communication

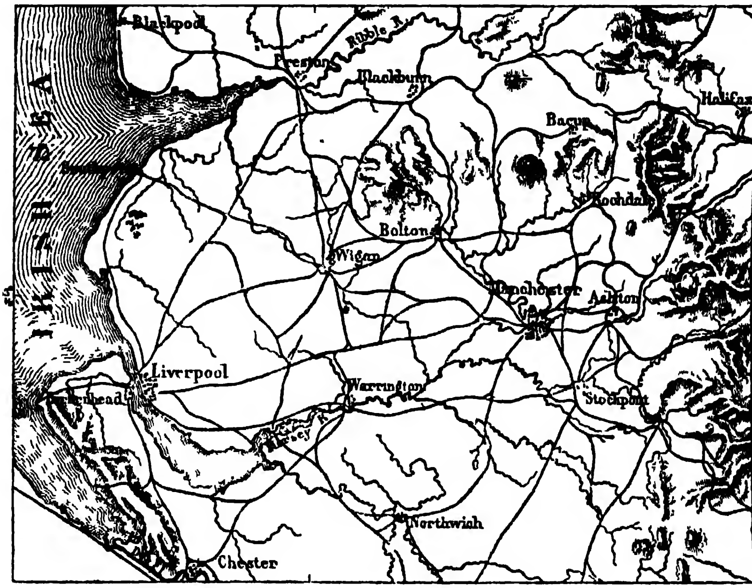


Fig. 202.—The Railways of Lancashire

has resulted in attracting to these districts a population truly enormous, when compared with the small area which they occupy. In the same way London, to which railways converge from all the points of the compass, increases its inhabitants at the rate of 50,000 a year, and in its onward march continually embraces within its boundary the towns, the villages, and the hamlets of the environs. London alone already contains nearly one-sixth of the population, and an attempt has been made to represent this fact in the following plate, in which London, Manchester, and Liverpool are represented by circular areas of a size proportional to the number of their inhabitants. Certain thickly-populated regions in Belgium, Rhenish Prussia, and Massachusetts are also crossed by railways in every direction; but everywhere else, except in the vicinity of capital cities, the network of lines is s[illegible] very far from being completed. Some continents are almost entirely without this mode of rapid communication. South America, which is twice the size of Europe, does not

possess more than 1800 miles of railway. If we except Hindoostan, the only railway in the continent of Asia is that from Smyrna to

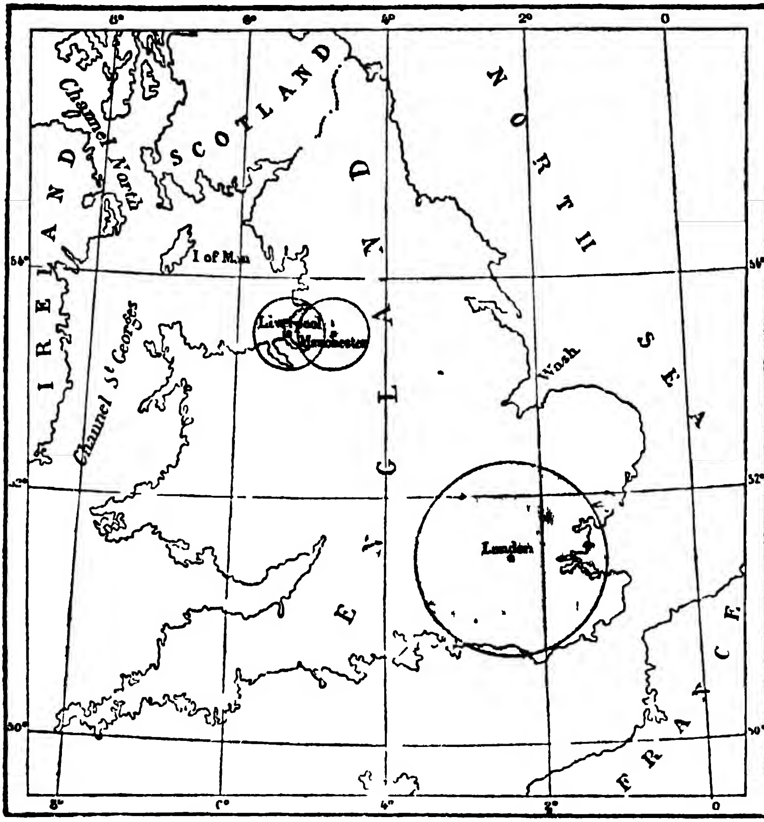


Fig 203 —Comparative populations of London and England generally.

Ephesus; Africa also is devoid of railways, except in the extreme north and south, that is, in the two colonies of Algeria and the Cape of Good Hope, and in the Nile basin, which as far as commerce is concerned is only a colony of Europe.

During the last forty years, two thousand millions of pounds have been expended in various countries in the construction of railways; and even this large amount is nothing but a small sum compared with that which it will be necessary to expend in order to continue and complete the work which has been undertaken. No one can fail to see that these expenses are very different from those which are

PASSES OF [illegible] MAURIENNE

Pl. XXV.

Drawn by A. [illegible]lemin

Engraved by Erhard

CHAPMAN & [illegible] LONDON

employed by man in the art of destroying one another, and that their tendency is to create fresh wealth and to bring nations into friendly relationship. The fraction of national savings which is able to escape the rapacity of taxation and the squanderings of luxury and debauchery, although still, alas, too small an amount, will serve however to bring to a happy completion those enormous works of which our ancestors never dreamed; and we must not think of styling even these works as "wonders of the world," because some day still greater works will be attempted. The Pyrenees, the Cevennes, the Vosges, the Jura, the mountains of Bohemia, and the Apennines are already crossed by railroads; the locomotive scales the heights of the Sierra-Nevada of California, at as great a height as 7020 feet, whilst on the east it crosses a pass of the Rocky Mountains 8240 feet high. At Soemmering, and at Breuner, the Alps have submitted to the hand of the engineer; Saint-Gothard, the Simplon, Mont-Genèvre will be surmounted in due course; and finally, for the last 11 years, the work has been going on of driving a tunnel 13,363 yards long under the mountains of Frejus, between the French village of Modane and the Italian town of Bardonnêche, whilst 16 miles to the eastward a temporary railway, following the windings and scaling the heights of the Mont Cenis carriage road, reaches an elevation of 6880 feet and then descends in zigzags into the abyss at the bottom of which is situated the town of Suze. In the time of Hannibal and the Romans and down to the earlier years of the present century, no one could travel from La Maurienne to Italy, except by the pathways of the two Mounts Cenis, or through formidable passes intersected by precipices and almost always obstructed by glaciers. Since 1840, one route enabled the travellers of the two nations to communicate with one another at all seasons; and now, the pressure of the two commercial currents which seek to be connected across the rampart of the Alps has become so strong that it has been found necessary to improvise a railway of a special construction, whilst waiting for the great international road which will overcome the obstacle of the Alps between Paris and Turin.*

The engineers who can pierce through mountains have no longer any fear of suspending their iron ways above the widest rivers or even over arms of the sea. In Canada, a viaduct nearly two miles long crosses the St. Lawrence; not far from the falls of Niagara, a bridge carrying four lines of rails crosses the abyss into which the water dashes down. In England, the Straits of Anglesea, the estuaries of

* The Mont Cenis Tunnel was opened in 1871.

the Mersey, Saltash, and many others, are crossed by magnificent tubular bridges; and sooner or later the two shores of the Bosphorus and of the "Phare" at Messina will be connected by bridges, over which railway trains will rush. Lastly, for some years past engineers have been emulating one another in proposing to do away with the gap, presented by the Straits of Dover, between the continental network of railways and those of Great Britain, either by a tunnel under the bed of the sea or by constructing a bridge 22 miles long between the two cliffs. This is far from being a mere chimerical dream: the money spent in the terrible contests of Solferino or Sadowa would have amply sufficed for the execution of this work. In a few years skill and perseverance will have reconstructed the isthmus which the waves took thousands of centuries to destroy.

In the same way as straits are no longer allowed to arrest the progress of the locomotive, so isthmuses have to open out for navigation and to complete the work of the remoulding of the earth. The ancients formerly tried their hands at these great works, but their attempts never attained any definite result. Thus the Greeks, and after them the Romans in the time of Nero, commenced at various times to cut a canal between the two bays, one in the Ionian Sea and the other in the Archipelago, which are separated by the isthmus of Corinth. At the spot chosen, the land to be cut through was not more than four miles wide, and rose from the two coasts in a gentle slope to a level of 190 feet in height. If we take into account the small dimensions required for a canal intended to carry only Greek and Roman galleys, the labour of excavation would not, at the present day, seem anything extraordinary; but the difficulties appeared insurmountable to the engineers of old, and the vessels which desired to pass from one gulf to the other were compelled to make a great circuit round the promontories and isles of the Peloponnesus, exposed to all the dangers of the main sea.

The navigable canal, commenced by Pharaoh Necho 25 centuries ago, between the course of the Nile and the Gulf of Suez, was a task more easy to finish successfully than cutting through the isthmus of Corinth; for the only point in question was to make, across the lowlands of the desert, a supply channel, bringing down the fresh water of the river to the Red Sea. One of the Ptolemies completed this work, which for a long time had been abandoned; after some centuries of interruption, Caliph Omar caused it to be repaired thoroughly by his lieutenant Amrou, and for some years it facilitated the exchange of commodities between the Delta of

the Nile and the towns of Arabia. At the present day, this water-road, having been re-dug without any difficulty by the French engineers, not only serves for the transport of merchandise and commodities between the fluvial basin and the Red Sea, but also supplies fresh water to the town of Suez, the inhabitants of which have been in danger of dying of thirst, on account of the deficiency of springs and rain-water; it also tends to fertilize the land which lies on either bank, which were formerly devoid of all vegetation. But this canal,

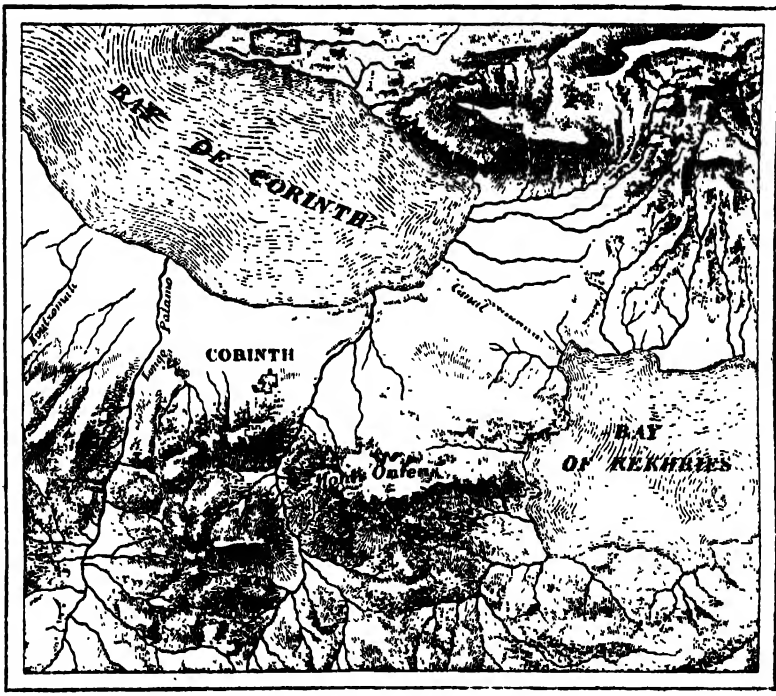
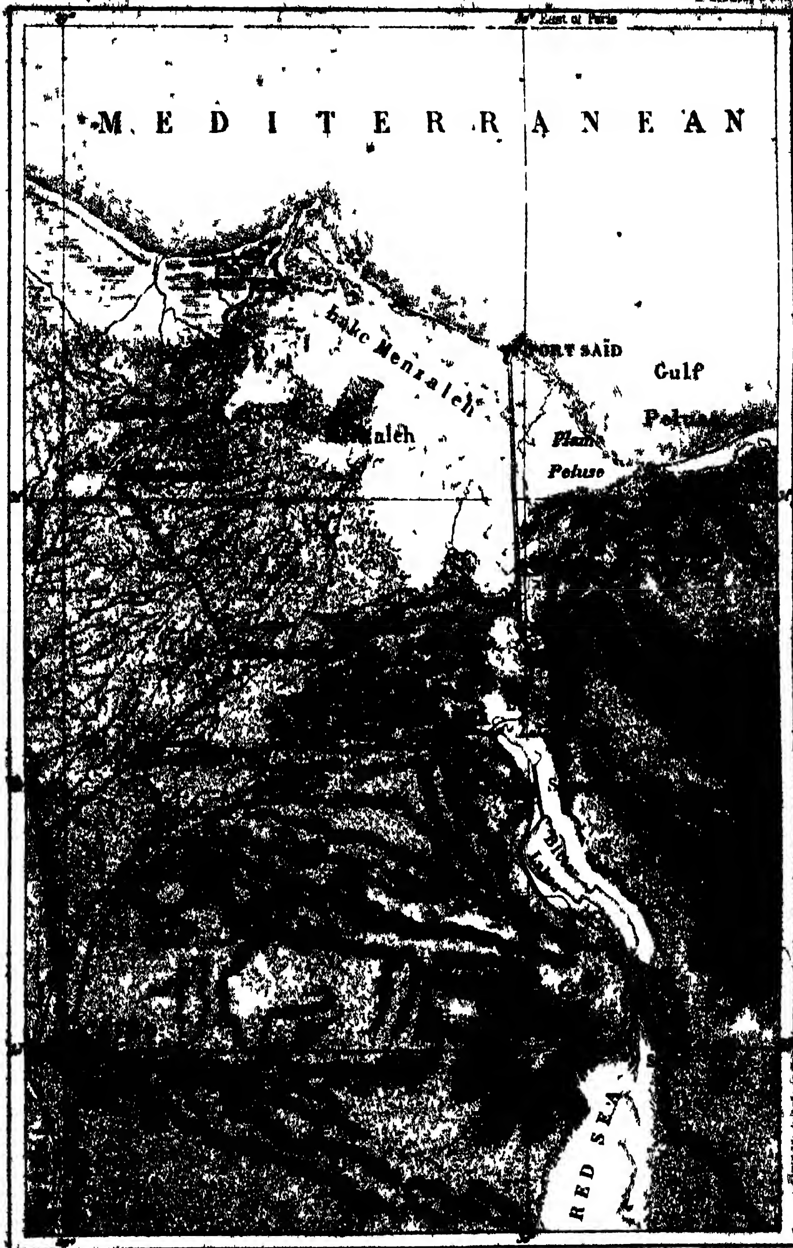


Fig. 204.—The Isthmus of Corinth.

although it is more useful and certainly more durable than our ancestors could ever have made it, is nothing more than a mere detail of the magnificent work commenced in 1864. The great canal, which has been in the course of construction since this date and was to be terminated on the first of October, 1869, is a real arm of the sea 90 miles long, re-establishing the communication which formerly existed between the Mediterranean and the Indian Ocean, as proved by the geological features of the district. The canal

is deep enough to receive ships drawing a great depth of water, and wide enough for two trains of boats to pass one another without difficulty; in addition it is provided with vast inland ports, in which a whole fleet can be laid up, and with two magnificent ports at each end, one of which, that of Port-Said, is already the most roomy and safe in the whole of the Mediterranean, next to that of Marseilles. The mass of earth which it was found necessary to move in order to open out the route for ships is not less than 95 millions of cubic yards, so that if the rubbish was thrown up in a heap, it would form a pyramid 31,470 feet in circumference at the base, with a height of 1100 feet. In consequence of the attraction which such an immense field of labour could not fail to exercise over the population of Egypt and of Europe generally, the desert has become inhabited and dotted over with gardens and oases; two important towns, Port-Said and Ismailia, have risen out of the sand; nearly 40,000 inhabitants have established their dwellings in these plains, into which the traveller could not formerly make his way without trembling. And what will these earliest groups of colonists be in comparison with the multitudes which will flock from every quarter when Port-Said and Suez have become new Constantinoples and receive the whole or even a part of the enormous traffic of nine millions of tons which until the opening of the canal went every year round the Cape of Good Hope, thus lengthening the nominal extent of their passage 7400 miles every voyage? Certainly, it does not seem out of the way to expend 12 millions of pounds on such an undertaking as this, looking at the fact that the merchants of Amsterdam, in order to spare their ships the short circuitous route through the Zuyder Zee and the passage of the Texel, have not hesitated to construct one canal, 50 miles in length, across the peninsula of Holland, and also another only 15 miles long, which have cost them not less than £2,400,000. The latter canal cuts through the peninsula at its commencement, and crosses the former lagunes and marshes of the Ij, which are being rapidly changed into magnificent *polders*.

The opening of the Suez canal must naturally be followed sooner or later by a cutting through one of the isthmuses of Central America. So early as the year 1528 Cortez, having ascertained that no straits existed between the Gulf of Mexico and the Southern Ocean, applied himself to the means of creating one, by cutting a navigable canal through the isthmus of Tehuantepec. Since the time when the former American colonies became free countries, and were liberated from the commercial trammels imposed as a right by a few houses in Seville and



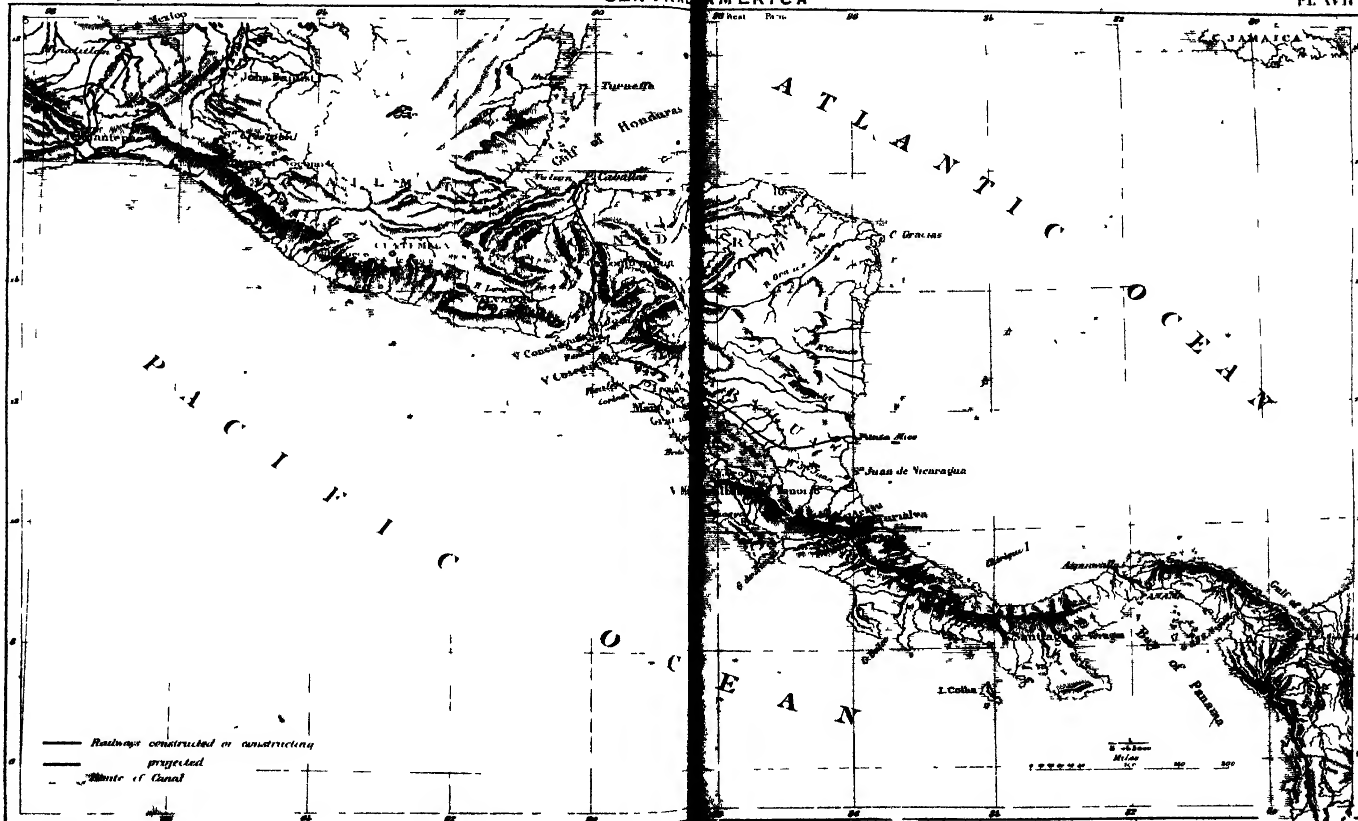
Drawn by A. Vuillemin Engraved by Erhard

Cadiz, projects for cutting through the isthmuses have presented themselves in large numbers, some laid down at hazard on merely fancy maps, and others studied with all the care that a knowledge of the country could suggest, and brought forward by men highly esteemed in science. The portion of Central America which engineers have vied with one another in crossing with their various plans for canals, either with or without locks, comprehends without exception all the narrow parts of the extensive district which joins Mexico and South America. The isthmus of Tehuantepec, and that of Honduras, the valley of San-Juan, and the narrow belt of country which separates the waters of the Pacific from those of the two lakes of Nicaragua and Munagua, the isthmus of Chirigni, the Rio Chagres and Panama, and Darien, the narrow stalk which connects the northern continent with the enormous mass of South America, have been in their turns extolled as the spots where the great commercial port of the world must necessarily be opened out. According to M. Jules Flachat, the sum that would be required for the easiest of these undertakings, that of Nicaragua, would reach an amount of £12,800,000, whilst the most costly plan, that which would take the course of the Atrato and the Truando, would involve an outlay of £30,000,000. This is a mere trifle compared with the treasures which are expended every year in buying warlike weapons and casting cannon-balls and bullets; but it is considered a large amount for a work of universal interest, the result of which will be to bring continents closer to one another and to hasten the day of the great reconciliation of nations. It is therefore possible that long years may still elapse before one of the American isthmuses afford a channel to fleets of commerce; and yet, if the sums wasted on the various financial markets in the promotion of fantastic joint-stock companies had been employed in some well-grounded scheme for the junction of the two seas, there can be no doubt that a great part of the work would have been now accomplished. In Nicaragua especially it would be comparatively an easy matter to open out a communication between the two Oceans. The Spanish trading ships used at one time to ascend freely right up into the lake, being impelled by the trade-winds; and even now steamboats successfully make head against the current of the rapids. By improving the port at the entrance and by straightening the course of the San-Juan in certain difficult reaches, admittance to the lake could again be opened to ships of from 300 to 400 tons burden; all that would then remain to be done would be to cut through the narrow tongue of land formed by Granada. But to the westward of

the island and the roadstead of Lapatera, where vessels would be completely sheltered from the surf produced by the trade-winds, Maximilien de Sonnenstern, the engineer, has discovered a pass 18 miles in length, the highest point of which does not rise more than 23 feet above the lake of Nicaragua, and about 147 feet above the Pacific.*

* Felix Belly, *A travers l'Amerique Centrale*, vol. ii. p. 405.

CENTRAL AMERICA



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CHAPMAN & HA ONDON

CHAPTER XXVI.

THE INDUSTRIAL POWER OF MAN.—THE ELECTRIC TELEGRAPH.—POSSESSION TAKEN OF THE SEA.—CULTIVATION OF OYSTERS.

It has been calculated by statisticians that, in the year 1860, all the machines working in Great Britain for the benefit of manufactures generally represented an amount of power put in force equivalent to that of 1200 millions of strong men: this considerably exceeds the collective force of the whole of mankind, for, among the 1300 millions of human beings existing, three-quarters of them are either too weak, too young, or too old, to be adapted for any continuous labour. And yet this enormous total of manufacturing power in England is increasing every year at a rate equivalent to that of several millions of "arms-power;" in France, in Germany, in Italy, in the United States, in Hindoostan, China, Japan, and Egypt, in fact, in all the countries where civilization has introduced its machinery, the increase of the motive powers applied to labour in general is taking place in a similar or still more rapid proportion. Thanks to winds, water-power, steam, and other natural agents which man has enlisted to do his work for him, manufacturing skill every year achieves a task of increasing grandeur, and is incessantly contributing more actively to modify the aspect of our globe.

But what are the wonders of to-day compared with those which science will some day give us the means of accomplishing? When we shall be enabled to lay hold of and to fetter so as to make it work for us at our will, the power exercised in a limited space by the sustained blast of one of the hurricanes of the West Indies; when we are enabled to employ the active force developed by the waves which break during a stormy winter on the dikes of Cherbourg, or even the flow of the tide which covers every month the shores of the Bay of Fundy; when we know how to deprive volcanoes of the terrors which they inspire, and to conciliate for our use the formidable power of the lava and the compressed gases which are at work in their abysses,—what works will be so colossal that labour

and boldness will recoil from them?* We may fearlessly assert, that all that man has hitherto done is but a trifle in comparison with what he will be able to effect in the future, when the forces at his disposal, instead of neutralizing one another, will be able to work in concert. If our rude ancestors, who inhabited caves during the stone-age, were to return among us, they would without doubt be too ignorant to understand, or even to wonder at, the immense progress made since the ages of barbarism.† And are we ourselves at the present day sufficiently advanced even to form an idea as to what the surface of the globe will be when man shall have, so to speak, reconstructed it, aided by the means of increasing power which will be furnished to him by a thorough knowledge of nature and her phenomena?

Among the material achievements of modern science, that which gives us the highest hope in respect to the future progress of mankind is the electric telegraph. By this invention man ceases to be connected merely with that part of the globe on which he treads so lightly, his liberty is set free from the obstacles imposed by time and space, and he becomes, as it were, personally present at all the points of space which the conducting wire brings into relation with his thoughts. To the power of his machinery, which might be compared to *muscular* force, he adds the *nervous* forces afforded by fibres stretching in every direction; news, transmitted from cell to cell, reaches the brain of man from all the ends of the earth, and his expressed wishes are flashed across continents so as to be transformed into actions on the other side of the globe.

The construction of electric telegraphs did not commence until about 10 years after the completion of the earliest railways; but owing to the comparative simplicity of the works requisite for the establishment of electric wires, the total length of telegraph lines already much exceeds that of the iron roads. For an expense of about £20,000,000 we have been able to set up more than 1,300,000 miles of wires, a length which would reach nearly 621 millions of miles, if we were to reckon all the double and multiple wires of importance; this is an extent equal to the length of a string which would encircle the globe at the equator as many as 25 times. The new wires unrolled every year would be sufficient to give another turn of the string round the whole circumference of the planet; it is the far-reaching stretch of the human will which is thus extended

* George P. Marsh, *Man and Nature*.

† Grove, *Address to the British Association*, Nottingham, 1866.

so far over the domain which it has made its own by its skill and energy.

Not only on the surface of the mainland, but also in the depths of the sea, does the electric fluid transmit the thoughts of man all round the globe. By about 15 wires which rest on the bed of the Channel or of the North Sea, Great Britain is connected with the coasts of France, Belgium, and Holland; Sweden and Norway are directly joined with Germany by wires across the Baltic; Sicily and Sardinia have, in spite of the Mediterranean, become portions of the Italian mainland. We can still recollect with what emotion we greeted the first interchange of thought flashed from one side of the Atlantic to the other, passing under the immense body of water 2200 fathoms deep and as broad as an eighth part of the circumference of the globe. These first words which the Old World thus sent to the New were words of peace and good-will; it was understood by all that the great fraternity of man had then asserted its existence in a most solemn manner; in spite of all the obstacles nature could offer, in spite of continents, seas, and space, widely-distant nations were beginning to be sensible of one common soul. After transmitting these words of peace and scrawling some indistinct syllables, the Transatlantic cable, as if exhausted by its first effort, and, as it were, ceasing to live, refused to respond to the learned electricians who were soliciting it on both shores of the ocean; silence had resumed its empire across the broad tract of water. But the persevering

Fig. 205.—The Transatlantic Cables

Anglo-Saxons did not succumb to the blow of this defeat: they again manufactured thousands of miles of fresh wire, and commissioned

their engineers and their most skilful mariners to lay it down in the bed of the ocean. Then, with an anxiety as great as that experienced on the eve of a decisive battle, they witnessed the departure of their finest ship, unrolling as it went the cable which was to unite them to their American brethren. Fresh misfortunes followed: the wire broke in the open sea. No matter; they laid down a third, and the mighty "Great Eastern" made her voyage across the Atlantic without ceasing for one instant to keep up a communication with the coast of Ireland, just as if she had left in her wake a long electric furrow. At the present time two electric telegraphs connect the two opposite continents, and efforts are being made to lay down others, between Lisbon and Rio Janeiro, and between Brest and New York. Lines, however, of no very great length, especially that from France to Algeria, by way of the Balearic Islands, have not been successfully established in a permanent way, the cables having often been broken; the cables also in the Eastern Mediterranean, the Red Sea, and the Indian Ocean have been frequently injured. A total length of 12,400 miles of telegraphic wires has been laid down in the bed of the sea between various parts of the world, its islands and peninsulas; but there does not at present exist any one continuous line which belts round the whole circumference of the planet passing across the continental masses and the depths of the ocean. The longest line, that between California and Calcutta, passing through New York, London, Vienna, Constantinople, and Bagdad, is not less than 12,400 miles in length.

The great undertakings which have been already accomplished on the coasts and in the depths of the ocean justify us in asserting that man has taken possession of it. At the present time the sea is no longer "an insuperable abyss," and the mariner is able to explore almost the whole extent of it. Nearly 200,000 ships traverse the waves between the coasts of the various continents and islands; more than a million of sailors have made their homes on the dreaded billows, and half their lives are spent in ships which float on the waves and are beaten by the tempest. Sea voyages become more and more frequent, and the number of travellers who cross every year from one side of the Atlantic to the other must now be reckoned by hundreds of thousands; they equal the number of passengers who travel from Great Britain to the Continent over the narrow waters of the North Sea, the Straits of Dover, and the Channel. Not only are the natural ports afforded by the bays and river-mouths improved by hydraulic works of every kind, but new harbours are opened for

ships on the most dangerous coasts. Thus the dreaded shoals of Holyhead, Kingston, and Howth, and the rocky islets of Cherbourg and Plymouth, have been utilized as foundations for jetties and embankments, inclosing large areas of water, where great ships may find a safe refuge. In other places, as at the mouth of the Danube, the two banks of the river have been pushed out to a considerable distance into the sea, so as to reach deep water.* At Portland, the summit of a hill has been thrown over into the sea so as to form an immense breakwater, inclosing a whole bay where fleets might safely manœuvre. The idea has even been started of constructing harbours in the open sea. M. Thomé de Gamond has proposed to utilize the Varnes bank, in the middle of the Pas-de-Calais, for establishing a great harbour of refuge on the track traversed every year by more than a hundred thousand vessels.

Another attempt at taking possession of the sea is that which has been made by the "farmer" of its waters. This attempt is not limited, like that of the hunter on the dry land or of the fisherman on rivers and in the ocean, to merely catching animals in order to make food of them; but, rising a degree higher in civilization, the "oyster-farmer" has learnt to imitate pastoral nations, and instead of, like a savage, destroying living beings without paying any attention to the maintenance of the species, he makes it his business, on the contrary, to increase the number of its individuals by rearing them, and takes care of them in order to ensure his future subsistence. Thus the "oyster-farmers" cover their submarine fields with faggots, stones, and tiles, to which the "spawn" sticks, that is, the innumerable multitude of small organisms which will ultimately develop into oysters. When the molluscs, after having escaped the thousand causes of destruction by which they are surrounded, have attained some little size in the beds, they are fished up and removed to fatten in reservoirs where they reach their full growth. The fishermen of the Ile de Ré, who commenced the cultivation of oysters scarcely 10 years ago, have already established beds which extend over an area of 15,500 acres, and they obtain from them more than 300 millions of oysters every year. This mollusc is also cultivated on the artificial banks of Arcachon, Marennes, in the bay of Saint-Brieuc, and on the shores of Cotentin. In England, also, the cultivation of the oyster is assuming an increasing importance, and is gradually taking the place of the former barbarous methods of fishing for them. But in the United States especially oyster culture has increased enor-

* See in *The Earth* the section entitled, *Rivers.*

mously. Out of the 50,000 millions of oysters which are eaten every year in America and Western Europe, the share in the consumption

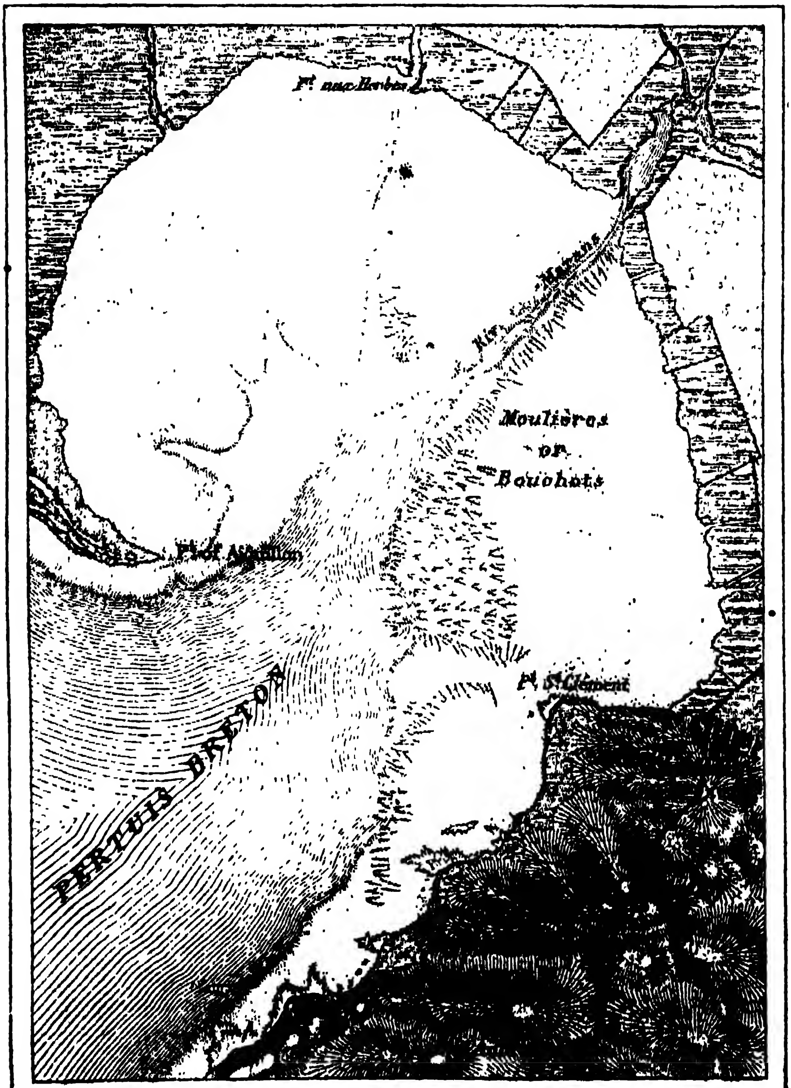

Fig. 206.—The Roadstead of Aiguillon.

taken by the United States is nearly 45,000 millions. The quantities

of mussels which the fishermen dredge up on the coasts and make articles of commerce are also most considerable. In the roadstead of Aiguillon alone, where the culture of this mollusc has been practised ever since the thirteenth century, more than 500 fishing-hurdles or ranges of palisades may be reckoned, on which the mussels hang in immense clusters; the mussel fishers collect them by millions every year off one palisade only.

The cultivation of marine plants has not yet been undertaken by man. All he does in this way is to collect the seaweeds on the beach, mixed with fragments of shell-fish thrown up by the waves, and to utilize them for manuring his fields. This employment of seaweed is however entirely local in its character, and is inconsiderable in extent. If only agriculturists desire it, they can find for all the arable land in the world an inexhaustible quantity of manure; to do this all that would be necessary would be to send fleets to gather cargoes of sea-wrack in the interminable prairies of sargasso in the Atlantic and Pacific Oceans.*

* See above, p. 114.

CHAPTER XXVII.

COMPARATIVE HARMLESSNESS OF HURRICANES.—PREVISION OF WEATHER.—MODIFICATION OF CLIMATES EFFECTED BY THE LABOUR OF MAN.

Another circumstance which singularly contributes in hastening to the "taking possession" of the seas, is the fact that winds and even terrible hurricanes have lost some of their power over man. Thanks to the previsions which science has enabled our mariners to exercise, these meteoric phenomena become less and less terrific; and their beneficent action in blending different bodies of air, is no longer accompanied, as it once was, by so large a number of local disasters. Guided by the appearance of the sky and of the sea as well as by the oscillations of the barometer, the captain of a ship sees beyond the horizon the tempest which is approaching, and fearlessly takes proper measures in order to avoid in good time the formidable cyclonic storm which is about to burst upon the sea. As far as regards a well-commanded steam-ship, "a hurricane is no longer a possible event;" the cyclone is nothing more than an ordinary whirlwind all round which a ship may sail without danger, keeping away from it if there is any fear of becoming entangled in the vortex, and on the contrary approaching it, if the direction of the tempest may be made favourable to its course. The hurricane, which was the terror of navigators in former times, may thus become in our days a powerful auxiliary.* In the vicinity of the coast, the danger of course remains very great, because the ship has not a free space before it; therefore when a hurricane is anticipated, mariners are compelled to put out as soon as possible into the open sea.

Coasts, along which the navigators of the olden time used servilely to creep, dreading to face the terrible Neptune, are now avoided by sailors, for it is on the coasts, and principally on the low-lying beaches, that nearly all the shipwrecks take place. The descriptive charts which are drawn up by the salvage societies to show the proportion of calamities occurring on the various points of the coasts of Great Britain and France, bear witness to the formidable nature of

* Bridet, *Étude sur les Ouragans de l'Hémisphère Austral.*

these dangers; out of 100 vessels, two on the average have to suffer disaster in each year. The seas which are tranquil and deep enough to enable vessels to sail at all times without fear in close proximity to the coast, are less numerous; the shores of the Mediterranean are no less sprinkled with wreckage than those of the ocean, and some of these spots, especially that portion of the curve which extends between Cette and Marseilles, are particularly dreaded. In

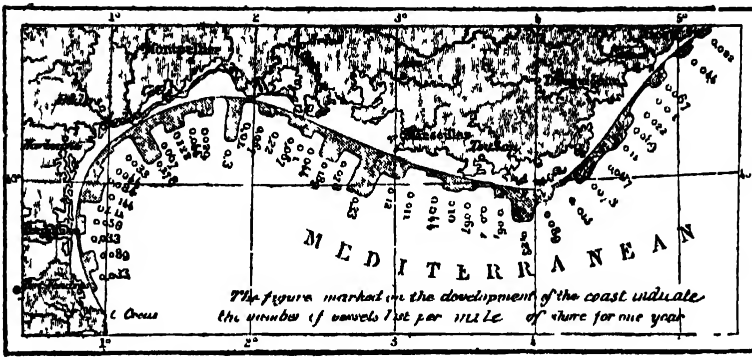

Fig 207—Shipwrecks in the Mediterranean

order to diminish the number of shipwrecks, attempts have very rightly been made to improve the ports, to open harbours of refuge, to light up dangerous coasts with beacons visible at a great distance out at sea, to point out shoals by means of landmarks and buoys, and to communicate with mariners by means of the telegraphy of semaphores; and above all, a precise knowledge of the movements of the atmosphere, enabling one to form an increasingly clear prevision of the phenomena of the weather, are the means by which disasters at sea may be best prevented. Navigation, especially steam navigation, which enjoys the immense privilege of speed, will have but very few dangers to fear when mariners understand the art of manœuvring in order to avoid tempests, and every vessel has become a floating observatory, as suggested by Maury, the illustrious American sailor.

At every period of history men have made it their business to endeavour to foretell the weather. Owing to the numerous advantages which are offered us by civilization, the practical utility of knowing beforehand any approaching meteorological changes has become less urgent, because in the present day we can to some extent shelter ourselves from the influence of these variations by our cloth-

ing, our dwellings, and our food. There are even some people who, by means of an altogether artificial mode of life, have arrived at the point of being unacquainted with the greater part of the meteoric agencies of the air. This was not the case with the nations of antiquity. Living in the open air or in ill-closed huts, seeking their livelihood in hunting, fishing, agriculture, or in rearing cattle, they were compelled incessantly to search the horizon in order to discover the earliest antecedent signs of wind, storm, and rain. By a constant examination of the heavens, the most skilful observers were enabled to discover either more or less accurately a great number of facts which placed them in a position to foretell the weather; especially in countries where the phenomena of the atmosphere took place with some degree of regularity, as in Egypt and the Indies, those who were called "wise men," on account of their knowledge of times and seasons, learnt to make fortunate prognostications as to the approaching changes of temperature which were not indicated to the common herd by any outward signs. Having been converted into proverbs which were repeated from mouth to mouth, a great portion of these predictions have come down to our time, and in the different localities where they were originally uttered one may now judge of the amount of truth which they afford. Many little known facts have been verified for thousands of years past by these popular sayings, and a great service would be rendered to science by collecting these scattered proverbs uttered in the infancy of nations.

Nevertheless, in their desire to know beforehand the various changes of temperature, experience is not the only thing to which men have appealed; they have sought to discover, in the movements of the stars, the future not only of the seasons but of their own personal destinies. They claimed to attain to a prescience of the variations of the weather by the apparitions and conjunctions of distant planets, and not by the phenomena of the atmosphere itself. These astrological chimeras, which moreover suggested to ambitious soothsayers the means of obtaining an ascendancy over the minds of others by the prestige of the supernatural, have not as yet entirely disappeared from science, and are reproduced from time to time under a borrowed garb more or less scientific. Without feeling ourselves compelled either to assert or to deny the influence exercised by the heavenly bodies on the phenomena of the terrestrial atmosphere, it is certain that, in order to attain ultimately the great end of foretelling the weather, it is necessary to proceed methodically by observations of ever increasing accuracy and completeness, made at all the

various points of the globe. By classing all the special facts, and by discussing them so as to give to each its just value, we shall gradually discover the general laws which bear upon them, and then day by day draw back the curtain which is spread over the field of our sight.

Although the resources of civilization have rendered us more independent of the variations in the atmosphere than our ancestors were, nevertheless the interests which are constantly placed in peril by unforeseen modifications of the temperature are immense, especially as regards agriculturists and sailors; added to this, the inquirers into this subject have a special incentive to urge them on in their studies, in the powerful attraction which is presented to them by the study of the laws of nature. It is beautiful to be able to recognize order and rhythm in what at first seems to be nothing but the caprice of the elements, and to trace beforehand in the heavens the course taken by those invisible forces, the incessant conflict of which produces all the variations of weather. Such is the ambition which, at the present time, may reasonably be entertained. Not very long ago Arago expressed a doubt whether man could be thus able to foresee the alterations of temperature and of meteoric agencies; but at the present day nearly all *savants*, emboldened by the grand discoveries made during the last few years, are on the contrary full of confidence, and look forward to becoming, at an early future, masters of all the secrets of the weather. In England, Admiral Fitzroy, in Holland, MM. Buys-Ballot and Andrau, in France, M. Marie-Davy and other meteorologists, have been able, owing to an attentive observation of the signs of the atmosphere and a comparative study of meteorological phenomena, to make an attempt to predict the weather two days beforehand; and more often than not their prognostications, placarded in all the ports on the sea-coast, have been found to be justified. M. Bulard, of the Observatory of Algiers, goes still further; he announces changes of temperature weeks and even months before they take place. Moreover, the comparison of the events with the predictions cannot leave any doubt in the mind; following the courses taken in space by the meteoric agents, is the plan pursued by the observer in order to be enabled to point out beforehand the points where, and the time when, the aerial currents will meet, where and when clouds will form, wet will fall, and the tempest will break. When, in their daily comparisons, meteorologists will be able to make a free use, not only of the whole network of European telegraphs, but also of all the wires upon the earth; when they

will be cognizant of the various daily phenomena observed at the American stations, and observatories, like advanced sentinels, are established at Bermuda, the Azores, St. Thomas, and the Havannahs, that is, at the various points from whence arise the winds, currents, and cyclones, which take their course obliquely across the Atlantic, then the prognostication of the weather will be placed on a sure basis. The *savant* will read beforehand the signs of the heavens, the mariner will know when he ought to remain in port, and the agriculturist will ascertain the best time for gathering in his crops.

There is, however, a triumph still greater than that of foreseeing the succession of meteorological phenomena, and that is the victory obtained by the modification of climates. In every age, man has been incessantly occupied in changing them by his labours of cultivation and by the amelioration of the soil; but this work has been carried out in an ignorant way, and too often the effect of man's activity has been to vitiate the air, or to render the alternations of heat and cold still more sudden and disagreeable. Thus towns, the temperature of which was always raised 3° or 4° by the assemblage in them of a large number of people, are at the same time converted into centres of pestilence, whence poisonous gases find their way from the lungs of one to another. In the same way, in other countries, the wholesale cutting down of forests which has taken place has resulted in disturbing the harmony of nature. The mere fact alone of the pioneer clearing some virgin soil effects a change in the network of isothermal, isotheral, and isochimenal lines which pass over the country. In several districts of Sweden where the forests have been recently cut down, the springs at the present time commence, according to Absjiönsen, about 15 days later than those of the last century. In the United States, the vast clearings which have been made on the slopes of the Alleghanies appear to have rendered the temperature more variable, and have caused autumn to encroach upon winter, and winter upon spring. Generally speaking it may be stated that forests, which in this respect may be compared to the sea, diminish the natural differences of temperature between the various seasons, whilst their destruction exposes a country to all the extremes both of cold and of heat, and adds still greater violence to the atmospheric currents. If we are to put faith in certain authors, the *mistral* itself, the terrible wind which swoops down upon the Cévennes and brings desolation into Provence, has been a scourge of mankind, and has blown in its full violence, only since the disappearance of the forests on the adjacent mountains. In the same way marsh-

fevers and other endemic diseases have often broken out in a district after the woods, or even mere sheltering screens of trees, have fallen under the axe.* As to the general flow of the surface waters and the climatic conditions which depend upon them, there is no room to doubt that the result of the clearing away of forests is a disturbance of the regularity of the above-named conditions. The rain, which, by the intersected branches of the trees, descends drop by drop and subsequently trickles slowly through the dead leaves and the network of roots, when the forests are destroyed flows down fast upon the ground and forms temporary rivulets; instead of descending by subterranean sources to the lower strata and springing up again in fertilizing springs, it runs off rapidly on the surface of the ground and is lost in the streams and rivers. Up-stream the ground is dried up, and down-stream the body of running water is so increased, that floods are converted into inundations, devastating the whole country along the river-side; dreadful disasters are thus brought about, similar to those which were caused by the Loire and the Rhône, in 1856.

But man is now able to take account of the influence which his agency has exercised upon climate, either by improving it or making it worse; and any mischief that he has done he is able to undo. He knows that by again planting woods he has the power of modifying the extremes of temperature and of equalizing the amount of rain; he knows that by developing a system of irrigation he is able to increase the fall of moisture, as has been proved by the observations made in Lombardy during the last century,† lastly, he can make a district healthy by draining the marshes, by clearing the surface of the land from decaying matter, and by modifying the various kinds of cultivation. This was the case in Tuscany, where the valley of the Chiana, once almost uninhabitable, into which the swallow scarcely dared to venture, has been completely set free from the marsh-miasmas by the rectification of an irregular slope, covered with pools and lagoons. In the same way, the marshes of the district which was the ancient Etruria, have become much less dangerous to the health of the inhabitants since the Tuscan engineers filled up the low grounds on the sea-shore, and have taken care to prevent the mixture of salt and fresh water which took place at the mouth of the streams. The amelioration of the air to be breathed is the mode by which man will resolve the important question of

* George P. Marsh, *Man and Nature.*

† Ibid.

acclimatization; for the only hot countries that are really unhealthy for colonists who are natives of a temperate zone, are the moist regions, the air of which is saturated with miasmas. Even now, in spite of wars and of interruptions (extending through centuries) of the works of improvement, almost the whole of Europe has been rendered healthy by the labour of its population, and at the present time the same work is being accomplished by the inhabitants of North America, the regions of La Plata, Algeria, the Cape of Good Hope, and Hindoostan; the enormous work which still remains to be done in rendering healthy the whole surface of the planet becomes every day easier, for now men recognize the power of association, and the means by which they can do so are furnished by science.

CHAPTER XXVIII.

INFLUENCE OF MAN ON THE FLORA AND FAUNA OF A COUNTRY.—ENCROACHMENT EFFECTED BY THE MORE COMMON SPECIES.—EXTENSION GIVEN BY AGRICULTURE TO CERTAIN CULTIVATED SPECIES.

THE first relation of man to the various animals which surrounded him must necessarily have been one of conflict and destruction. The great battle of life was inaugurated by massacre. To eat or be eaten—this was the alternative, not only for man but also for the great cave-bear, the Attic lion, the *Machairodus*, and many other carnivora of past ages. There is no doubt that the struggle may for a long time have been indecisive, and perhaps in many places man may have been vanquished; but, after the various chances and changes of the conflict, the terrible wild beasts were ultimately killed down to the very last individual. Man, being more subtle than these monsters, and more skilful in hiding himself and in surprising them, was also ingenious enough to avail himself of artificial weapons, clubs, pointed bones, and axes or maces of stone, and was the conqueror in the conflict, whole races having disappeared before him. To say nothing of those animals which were exterminated at some unknown epoch in prehistoric times, it is probable that the *Schelk* of Germany * and the Great Stag of Ireland were destroyed by hunters less than 10 centuries before the present era. In our own time, the buffalo, the lion, the rhinoceros, and the elephant are constantly giving way before the advance of man, and sooner or later they, too, will become extinct. In thickly-populated countries all the wild animals are in their turn destroyed, and are replaced by beasts which we use either as slaves or companions, such as the ox, the dog, and the horse, or those animals which, like the pig, are nothing more than walking masses of butchers' meat.

There are several races of birds the extinction of which must doubtless be a reproach to man; among these we may mention the *Alca impennis* of the Faroe Isles, the *Dodo* of the Mauritius, the *Solitaire* of Reunion, the *Lory* of Rodriguez (*Psittacus rodericanus*),

* George P. Marsh, *Man and Nature*, p. 85.

the *Æpiornis* of Madagascar, the 12 or 14 species of *Moas* of New Zealand, the *Apteryx* and the *Palapteryx*.* M. de Lungershausen also points out as being extinct or in the course of becoming extinct, seven curious species of birds in the Sandwich Islands, Tahiti, New Zealand, Norfolk Island, and the Samoan Archipelago, which have been hunted to destruction by man, or by his companions the dog and the cat.† The sea-cows of Steller (*Rhytina Stelleri*), the enormous *Cetaceæ* weighing 22,000 lbs. which were discovered by the geologist of that name and his companions in 1744, and frequented in great numbers the coasts of Behring Straits, became completely extinct in the course of 27 years, and since 1768 not one of them has been seen; not even an entire skeleton is left. The whale, which recently enjoyed a short respite owing to the American war and the working of the petroleum springs, is now again most energetically pursued, and soon will not find any sea where it can take refuge; the seals are every year slaughtered by hundreds of thousands; the sharks themselves diminish in number along with the fish which formed their prey, the latter having become the spoil of the fisherman. The butchery year after year of the birds which feed upon insects has resulted in a formidable increase of the numerous tribes of ants, termites, locusts, caterpillars, &c., and in the same way the cetaceæ and fish which have disappeared are replaced by myriads of *medusæ* and *infusoria*.

With regard to this subject, Mr. Marsh expresses an opinion which at first sight cannot fail to surprise, but is none the less worthy of being taken into serious consideration. In his opinion, the very remarkable phenomena of the phosphorescence of sea-water has become more frequent in modern times, and more beautiful than it was 2000 years ago. Homer, who often speaks of the "thousand voices" of the Ægean Sea, makes no mention of its thousand glimmerings. In the same way, the poets who have represented Venus as springing from the foam of the sea and have peopled the "watery abodes" with so many nymphs and divinities, have not given us a description of the sheets of liquid gold on which, during the night, the bright shining goddesses were used to recline. The love of the Greek poets for broad day and the full light of the sun might tend to explain this strange silence; but why is it that *savants* also have maintained such a sobriety of language in describing this very extraordinary appearance of the phenomenon of the phosphorescent

* Owen;—Ferdinand von Hochstetter, *Neu-Seeland*, p. 447, &c.

† *Ausland*, No. 30, 1868.

glittering of sea-water? Aristotle, who speaks but briefly of it, attributes this light to "the greasy and oily quality of the sea." Ælian, the compiler, mentions the gleam emitted by the seaweed on the shore, and Pliny, the encyclopedist, tells us that the body of a species of medusa emits a certain brilliancy when it is rubbed against a piece of wood. This is a point to which science had reached before the observations made by Americus Vespuccio on the phosphorescence of tropical seas. Since this epoch there is not probably a single traveller who has not remarked on the jets of light springing forth during the night-time round his ship, not only in the West Indian seas, but likewise in the Mediterranean, on the European coasts of the Atlantic, and near the icebergs of the Polar Ocean. If Mr. Marsh's ingenious hypothesis is true, those among us who walk along the shore or sail over the sea when the waves are, as it were, on fire, enjoy a spectacle much more splendid than ever was given to our forefathers to contemplate. This, however, would be but a poor compensation for the ravages which have been made by our fishermen.

The action of man has also caused a rupture in the harmony primitively existing in the flora of our globe. The colossal trees in our forests are becoming more and more rare, and when they fall they are not replaced. In the United States and in Canada, the noble trees which astonished our first colonists have for the most part been felled, and in more recent days, before the finest forests in the countries of Mariposa and Calatrava became national property, the Californian pioneers had cut down, in order to convert into planks, many gigantic sequoias which had attained a height of 380, 390, and even 400 feet. This is perhaps an irreparable loss, for nature requires hundreds and thousands of years before she can supply the sap necessary for these enormous trees, and mankind, too impatient for proper enjoyment of it, and too indifferent to the fate of future generations, does not as yet sufficiently feel the extent of its own duration, so as to induce it to take thought for the careful preservation of the beauty of its forests. The extension of the agricultural domain, and the requirements of navigation and manufactures, also result in reducing the number of trees of an average size. At the present time they are diminishing in number at the rate of millions every year. Even the toy-manufactories, and the chemical match factories, to say nothing of the ship-building yards, require whole forests for their annual consumption. To make up for this, in all the countries of the world, herbaceous plants multiply, and are covering areas of increasing extent. One might almost fancy that man

was jealous of nature, and sought to dwindle down all the products of the earth so that they should not surpass his own level. Even now, as the natural consequence of the struggle going on between the various vegetable species, those which are common to several countries tend to smother gradually the more feeble species which try to hold their ground in some more limited district. Added to this, man also contributes towards the destruction of the original flora by increasing the field of growth of the invading plants. His migrations enable him to reclaim fresh tracts of land, and he sows them with the seed of civilized countries; in his course of cultivation he assails the mountains, marshes, and savannahs, where the local species have taken refuge; by his pathways, his roads, and his canals, he spreads far and wide, on a soil perhaps ill-adapted for them, the plants which surround his dwellings and grow in his fields. Not only in more or less extensive portions of one and the same zone do the vegetable species which are parasites of man increase their field of growth, but, at the very extremities of the world, they keep on annexing newly colonized lands. Just as European plants encroach on the indigenous species, so do the imported animals, delighting in their new climate, drive victoriously before them the representatives of the former local fauna. The pig, again become wild, has taken possession of the forests of New Zealand. The rat which once frequented the two islands, has been pushed out by the brown rat escaped from English ships, and the conqueror in the strife has himself become extinct in his turn, before the European *mus* tribe. The New Zealand fly carefully avoids his European rival, who has come all round the world, in order to drive him out from the huts of the islanders. As the Maoris sadly remark, "The white man's rat drives away our rat, his fly drives away our fly, his clover kills our ferns, and the white man will end by destroying the Maori." * One can well understand the despairing cry uttered by Michelet in his book *La Montagne*:—"Commonplace ideas and things will prevail!"

Oh, no! the ideal of man is the ideal which will always prevail. As long as this ideal is nothing else but the mere reclamation of ground for cultivation everything will be sacrificed to this point,—the variety and originality of species, and all the beauty of vegetation; but when the desire of obtaining productive crops from the earth is supplemented by that of adorning it and of giving to it all the splendour which art adds to nature; when agriculture, at last delivered from that fear of poverty which now persecutes it, and in

* Julius Haast, von Hochstetter, Oscar Peschel, *Ausland*, 19th February, 1867.

possession of that leisure without which it is nothing but a slave of hunger, will be enabled, like the amateur gardener, to busy itself in varying species and tastefully grouping them, and in developing elegant or magnificent forms of vegetation, no doubt it will succeed in materially modifying the vegetable world according to its desire, and in giving it, instead of its primitive originality, a new beauty which will respond to a sentiment of æsthetic taste.

Taking the point of view of the distribution of species, the principal result of agriculture has been to give a widespread extension to certain plants which are used either for the food of man or for the requirements of his industrial skill. The rice-plant, wheat, maize, the vine, the cotton-plant, the coffee-plant, each now covers millions of acres. The various cereals, although much less in number when compared with the 500,000 species of other plants, extend over an area of soil which cannot be estimated at less than a fiftieth part of the surface of the earth; in some regions, as in North America, fields of corn may be seen some thousands of acres in extent, undulating away to the furthest horizon like lakes agitated by the wind. The plants cultivated by man have so extensively exceeded the limits of their natural field of growth, that, out of the 157 species more generally cultivated, there are 72 which have not yet been recognized in their wild state, and as to the identity of which botanists still experience some doubt.* Until a quite recent date wheat was known only as an agricultural plant, and it was looked upon as a kind of miraculous source of wealth, when M. Balansa found it growing spontaneously on a mountain in Asia Minor.

Northern nations push on their cultivation of the ground to a point within the polar circle and very near the extreme limit where forests are found to grow. On the coasts of Norway, barley, which is cultivated nearer to the pole than any other cereal, does not succeed with any degree of certainty in districts above 66° of latitude; but it may be seen here and there, in sheltered valleys, almost up to the northern extremity of the Scandinavian peninsula. The most northern locality in which the inhabitants have found courage enough to cultivate it in spite of the climate, is Elobaken, in 70° of latitude. In Swedish Lapland the cultivation of barley stops short at a point ninety miles further south; and yet the annual crops are generally speaking only half ripe, and the farmers have to dry them in kilns; at Enontekis, a satisfactory crop is not obtained oftener than once in every three years. In other northern countries which are not, like

* Alph. de Candolle, *Géographie botanique raisonnée.*

Scandinavia, under the influence of the Gulf-stream, barley cannot be grown with much hope of success except in districts situated considerably to the south of the polar circle. But in every spot in the frigid zone where any groups of civilized inhabitants have established themselves, in Siberia, Labrador, and Greenland, these "outcasts" as it were of the human race, have by dint of labour extorted from the ground a few vegetables belonging to more temperate climes, such as cabbages, turnips, lettuces, and spinach, half-starved plants which would certainly refuse to live in the ice-bound soil, were it not for the indefatigable care of the gardener who sowed them. On the slopes of the Swiss mountains man has likewise carried cultivation far beyond its natural limits. In many valleys of the Alps fields of rye, barley, and oats are to be seen at an elevation of 5000, 5250, and in the Val Tomanche, even at a height of 6509 feet above the level of the sea, scarcely 2300 feet below the limit of perpetual snow.* The highest village in La Maurienne, in Savoy, is on an average 5898 feet above the sea; nevertheless, the inhabitants have given it the name of Bonneval, inspired by a kind of gratitude towards the land watered by the mountain stream Arc. On the slopes which face the southern sun, the villagers indefatigably cultivate both barley and rye; but it must be confessed that the crops are extremely late in maturing. The sowing takes place in July on fields where the snow has been melted by spreading on them black earth or barley stubble, and often in the month of August or at the beginning of September in the next year, the fields are still green; fourteen months are required to ripen the harvest. In consequence of a truly heroic conquest effected by man's industry, cultivations on the northern slope of the Valais Alps are pushed upwards to an elevation averaging 330 feet higher than on the southern slope, which is nevertheless exposed to the beneficent influence of the sun; the fact is, that the northern population, having a smaller extent of good land at their disposal, exercise more assiduity in their labour than the southern farmers.

M. Rosenthal, of Breslau, has enumerated no less than 12,000 plants employed either as articles of food or for their curative virtues and their utility in manufactures; but the most frequently cultivated species,—those which supply us with food, clothing, and all that is requisite for life—in the absence of which man would disappear from the earth—constitute but a very small portion of the earth's flora. Europe and Western Asia are perhaps the districts which have supplied to the human race the most valuable species of vegetables;

* Charles Martins, Note à la *Météorologie* de Kämtz.

even in the times of the Chaldeans and the Pelasgi, these portions of the ancient world had bestowed on agriculture more than half of the treasures which she possesses. The Indies and the Sunda Archipelago, so rich in their vegetation, are the habitats of about one-fourth of the plants used in agriculture and manufactures, and the remainder come to us almost entirely from South America, which, as regards the multitude of indigenous plants, and taking its area into consideration, is certainly the wealthiest continent of all. There is only one species of high importance among cultivated plants, the date-tree, which finds its origin in Northern Africa. With regard to Australia, New Zealand, and the United States, none of these countries have as yet supplied to mankind any one plant of essential utility either for food or agriculture, if we except the materials requisite for the building of houses and ships.

It is an evident fact that men, too much the slaves of routine in their course of cultivation, have as yet turned to account but a very small number of the plants which might be useful to them, and among those that are cultivated with the greatest care many are species of a poisonous nature, such as opium, the betel-root, and tobacco, that odious weed, the use of which weakens the body and stupefies the mind! To say nothing of the various species of trees which have not hitherto been worked for building purposes, how many American plants there are, neglected by or even unknown to botanists, which might be useful either for the food of man or for the cure of his maladies, either by means of their stems, their bark, their fruits, their flowers, their germs, or their roots! Not long back our agriculturists made a most important acquisition in the virgin forests of Bolivia and Peru: they have taken possession of the Peruvian bark tree with a view of converting it into a *cultivated* plant. The natives, too eager to avail themselves of its virtues, knew of no better plan than that of cutting down the tree and peeling off its bark; they traverse the forests in search of the *cinchonas*, and when they have found them, the axe is at once laid to them, and in the course of a few hours these trees, which might have supplied numerous crops of bark throughout a whole century, lay despoiled upon the ground. Fortunately, Clement Markham, the traveller, was successful in taking up a few young plants, and at the present time we have the *cinchona* growing in cultivated forests in Ceylon, the Island of Java, and on the mountain-slopes of the Himalayas and the Nilgherry hills.

CHAPTER XXIX.

INFLUENCE OF MAN ON THE BEAUTY OF THE EARTH.—DISFIGUREMENT AND EMBELLISHMENT OF THE LAND.—THE DIVERSE ACTION OF DIFFERENT NATIONS.—THE APPRECIATION OF NATURE.—THE PROGRESS OF MANKIND.

THE action of man is so powerful an agency in draining marshes and lakes, in smoothing down the obstacles between different countries, and in modifying the primitive distribution of animal and vegetable species, that these very facts become of decisive importance in the changes which the outward surface of the globe is undergoing. This action of man may embellish the earth, but it may also disfigure it; according to the manner and social condition of any nation, it contributes either to the degradation or glorification of nature. Man moulds into his own image the country which he inhabits; after long centuries of reckless use of it, the barbarian gives to the earth he lives on an aspect of rough brutality, whilst by an intelligent system of cultivation, civilization makes the country radiant with grace and with an impressive charm; he may humanize it, so to speak, so that any stranger passing through it feels a welcome when he enters it, and that he may safely repose in its bosom.

As if merely encamped, like a passing traveller, the barbarian robs the soil without returning to it by cultivation and thoughtful care that which he extorts from it; he ultimately succeeds in completely devastating the country which he uses as his place of abode and rendering it uninhabitable. The surface of the earth presents numerous instances of devastation of this kind carried on without mercy for the soil. In many a spot man has changed his native country into a desert, and "the grass has ceased to grow where he has placed his foot." A large portion of Persia, Mesopotamia, Idumea, and various countries of Asia Minor and Arabia, which used "to flow with milk and honey" and once fed a very considerable population, have become almost entirely sterile and inhabited by a few miserable tribes, living by pillage and the most primitive style of agriculture. When the powers of Rome gave way under the

attacks of barbarian invaders, Italy and the adjacent provinces, exhausted by the unintelligent labour of slaves, were to a great extent changed into deserts, and even at the present day, after two thousand years' fallow, vast tracts of land which were brought into cultivation by the Etruscans and the Liculi, are now useless heather or unhealthy marshes. In consequence of causes of a like nature which resulted in the impoverishment and ruin of the Roman Empire, the New World itself has lost, in an agricultural point of view, a considerable portion of its territory; many a plantation in the Carolinas and in Alabama which was reclaimed from the virgin forest not more than half a century ago, has totally ceased to be productive, and is now nothing more than an abode for wild animals. In Brazil and Columbia, naturally the most fertile countries of the whole earth, a few years are sufficient for exhausting the soil by means of a system of cultivation which is a mere robbery from it. The trees are burnt down, and maize is sown over the ashes, and the same crop is incessantly removed year after year, until it is smothered by a fresh growth of brushwood. This is burnt for the second time, and maize is sown again. Ultimately, ferns and a slimy, fetid sort of grass called *capim gordura* make their appearance, and the land is then destroyed for the purposes of cultivation.

The question as to how far the agency of man serves either to adorn or degrade the aspect of nature may seem an idle one to minds of a so-called positive tendency; but it none the less assumes an importance of the highest order. The development of mankind is bound up most intimately with the surrounding conditions of nature. A hidden harmony springs up between the land and the nation which is nourished by it, and if any society is imprudent enough to lay a disturbing hand on the elements which form the beauty of its territory, it is ultimately sure to repent of it. In a spot where the country is disfigured and where all the grace of poetry has disappeared from the landscape, imagination dies out and the mind is impoverished; a spirit of routine and servility takes possession of the soul, and leads it on to torpor and to death. Among the causes which, in the history of mankind, have caused the extinction of so many forms of civilization, we must place in the first order the reckless violence with which most nations have treated the soil which nourished them. They cut down the forests, exhausted the springs, and made the rivers overflow, and after thus injuring the climate, surrounded their towns with a belt of marshy and unhealthy land; and then, when the nature which they profaned showed its hostility

against them, they began to hate it, and being unable like the savage to fall back on forest-life, they allowed themselves to fall into deeper and deeper degradation through the despotism of priests and kings. "Vast domains have been the destruction of Italy" is the opinion of Pliny; but it must be added that these vast domains, being cultivated by the hands of slaves, had disfigured the land like a leprosy. Historians have been struck with the extreme decadence of Spain since the days of Charles V., and have endeavoured to explain it in various ways. In the opinion of some, the chief cause of the ruin which has befallen the nation was the discovery of gold in America; in the opinion of others, the cause was the religious terror organized by the "holy brotherhood" of the Inquisition, the expulsion of the Jews and Moors, or the sanguinary *auto-da-fé* of heretics. The fall of Spain has been also attributed to the iniquitous impost of the *alcabala*, and to the system adopted from the French of despotic centralization. But is not the kind of madness with which the Spaniard has felled the trees for fear of the small birds "*por miedo de los pajaritos*" a point to be considered in this terrible decadence? The land has become yellow, stony, and bare, and has assumed a repulsive and frightful aspect; the soil is impoverished, and the population, which for two centuries has been diminishing, has partially relapsed into barbarism. The small birds are well avenged.

Even in our own days and among nations the most advanced in civilization, numbers of the works of man have been attended with the fatal result of impoverishing the soil and disfiguring the face of nature. Taken as a whole, mankind has not yet emerged from his primitive barbarism. The work of deterioration assumes a different aspect among different nations according to their systems of agriculture, the variety of climates, and the diversity of manners and of national character. Arabs, Spaniards, and Spanish-Americans completely fell the trees and leave the face of the country to dry up and become yellow in the sun; Italians and Germans, on the other hand, scandalously mutilate the trees which they do not cut down, and give them the aspect of posts or broom-sticks; the French divide their land into innumerable parcels producing different kinds of crops, which looked at from a distance on the hill-sides resemble many-coloured draperies spread upon the soil. In the United States the land is cut up into geometrical squares, all uniform and with similar bearings, in spite of the undulations and risings of the ground. Lastly, in some countries the proprietors of land, either

poor peasants or great lords, surround their domains with defensive walls and hem them in with ditches as if they were besieged fortresses; this is done even by the miserable Irishman, the poorest among men, who encloses with a high earthen bank his bit of garden-ground containing nothing but ill-growing plants. How many countries there are in Europe through which one may travel for whole hours without finding a single spot on which an artist's glance might rest with any degree of satisfaction.

There are others besides the "rough tiller of the soil," so jealous of his patrimonial landmarks and so pre-eminently eager to obtain abundant products, who are often at work in disfiguring the aspect of the land in which they live; indeed, some of those who profess the greatest admiration for nature are in the habit of systematically degrading the most beautiful sites. In the environs of towns, the districts supposed to be country are cut up into enclosures, and are only represented by closely shorn shrubs, and beds of flowers of which a glimpse may be obtained through iron railings. Many of the German princelings, vitiated by a foolish sentimentalism, have defaced the most charming landscapes by carving pedantic inscriptions on the rocks, by adorning their lawns with fanciful tombs, and by making their soldiers mount guard in front of the points of view which they desire to point out to strangers. Multitudes of French *bourgeois*, in their mean love for a cramped and symmetrical style, have gone so far as to check the rise of the sap in the trunks, in order to create dwarf varieties and to give to trees geometrical forms or the fantastic appearance of monsters and demons. The grave Dutch merchants of the last century were not satisfied with their garden-walks unless they were edged with lime trees having their heads clipped into the shape of a ball and their trunks coloured white; and the trees at Brouck are still painted with oils and zinc-white. The gardeners of the Emperor Yang-Ty were in the habit of replacing the flowers and leaves which fall from the trees by artificial foliage and flowers made of silk, the latter being impregnated with perfume so as to render the illusion more complete.*

And how far do the highest aspects of nature find their due recognition among us? On the sea-coast, our most picturesque cliffs and our most charming shores are, in many localities, monopolized either by jealous proprietors or by speculators who appreciate the beauties of nature in much the same way as a money-changer values an ingot of gold. In much-frequented mountain districts a similar

* Meyer, *Die schone Gartenkunst.*

rage for appropriation takes possession of the inhabitants; the landscapes are cut up into squares and sold to the highest bidders; every natural curiosity, the rock, the cave, the water-fall, the glacier, everything, down even to the sound of an echo, may become private property. The very cataracts are farmed out to contractors who surround them with wooden fences in order to prevent non-paying travellers from contemplating the tumult of the waters, and then, by dint of laudatory articles in the public press, coin, as it were, the very light which plays in the broken water-drops, and the break of the wind which spreads clouds of mist over the abyss, and convert them into hard ready cash. No traveller can fail to experience a feeling of deep mortification when he compares the Niagara of to-day, such as men have made it, with the former "thunder of the waters," when it was left in the simplicity in which nature gave it to us. Hideous buildings, mills, workshops, hotels, and warehouses, have taken root on the cliffs; advertisers, speculating on the beauty of Niagara for the sale of their merchandise or of their drugs, have posted up their dirty and lying placards in front of the roaring cataract; other persons, still more disagreeable in their ingenuity, have vainly attempted to add some poetical features to the scenery by erecting Chinese Kiosks and Gothic turrets. The trees and their verdure which formed so appropriate a framework to the white hue of the water have fallen under the stroke of the axe, and the body of water itself is diminishing every day owing to the side channels which are dug by the mill owners to draw water from the Niagara for driving their machinery. Let the energy of man utilize, if it will, the immense power of the cataract; nothing can be more advantageous! But in this work of improvement the beauty of the spot has not been respected.

This depravity of taste, which impels men to deface the most lovely scenery, finds its origin in ignorance and vanity, and is henceforth condemned by the verdict of mankind; the mind of man now seeks for beauty, not in vain and purely outward imitations or in a fantastic and false style of decoration, but in the intimate and deeply-seated harmony of his work with that of nature. The man who really loves the land in which he lives knows that his duty is to preserve or even to increase the beauty which it possesses; but if a reckless system has defaced that beauty, then it is incumbent on him to endeavour to restore it. Comprehending the fact that his own personal interest is blended with the interest of all around him, he will repair the injuries committed by his predecessors, he will

assist the soil instead of inveterately forcing it, and will work hard for the beautification as well as the improvement of his domain. He will not only know, in his position as an agriculturist and a manufacturer, how to utilize the products and forces of the globe, but he will also learn with an artistic eye to give an additional grace and majesty to the scenery which is most charming. Having become "the conscience of the earth" by that very fact, man assumes a responsibility as regards the harmony and beauty of nature around him.

Under the rude hands of the conquerors of Rome and during the unhappy period of the middle ages, the thousands of slaves who cultivated the soil were but little able to comprehend the beauty of the land on which their miserable lives were spent; and any sentiment that inspired them with respect for the scenery which surrounded them must necessarily have been of a vitiated character. The bitterness of existence must then have been much too intense for them to experience any pleasure in admiring the passing clouds, the rocks, and the trees. Then on every side were quarrels, hatreds, sudden terrors, wars, and famines. The caprice and cruelty of the master was the law of the enslaved; in every unknown face they seemed to recognize a murderer; the names of stranger and enemy were then synonymous. In a society of this kind if a brave man wished to combat his destiny and to preserve the self-consciousness of his own soul, the only thing he could do was to be joyous and ironical, to scoff at the strong and especially at his master; but if he contemplated the earth nothing remained for him but grief. The splendour of the loveliest features of nature which surrounded them could not but remain unknown to the men who, influenced by a vague terror, sedulously kept up by sorcerers of every kind, ever fancied that, in every cave, in every deeply-hollowed road, in the mountain-gorge, and in the dim silence of the woods, they could discern hideous ghosts and horrible monsters, partaking of the natures both of the beast and the demon. What strange ideas must have been entertained of the earth and its beauties by those monks of the middle ages, who, in their maps of the world, were always in the habit of drawing, by the side of the name of every distant country, strange animals vomiting out fire, men furnished with horses' hoofs or fishes' tails, griffins with the heads of rams or bulls, flying dragons, and headless bodies with wild staring eyes placed in the middle of their breasts!

When the incessant warfare of the middle ages had come to an

end, the desire of every man who had escaped in the conflict must have been to secure for himself some charming and sheltered home; the bolder features of nature only produced fear, and all he asked for was peace. The ideal of the generations which followed one another from the *Renaissance* to the French Revolution is betrayed by the character of the sites chosen by both princes and lords for building their country seats. But a very small number of these palaces occupy a position which affords a view of a magnificent horizon of mountains and rocks; in many localities, especially on the shores of the lake of Geneva, the country houses built by the rich proprietors of the adjacent land turn their backs to the scenery which now appears to us the grandest. Instead of an aspect of nature too impressive and too wild for him to take pleasure in contemplating it, man then preferred a limited area of view, which the imagination could easily embrace, such as a curtain of gently sloping hills, a little stream winding along under the shade of alders and weeping-willows, charming avenues of clustering trees, and lawns and lakes ornamented by statuary. They valued these elegant graces far above the magnificent simplicity of a widely extending prospect.

The nations who at the present day are placed, in consequence of their pre-eminence in civilization, in the front rank of mankind, take, generally speaking, but very little trouble in the embellishment of nature. Being much more devoted to industrial than artistic skill, they prefer power to beauty. The universal wish of man is to adapt the earth to his requirements, and to take complete possession of it in order to derive from it its immense treasures. He covers it with a network of roads, railways, and telegraphic wires; he fertilizes its deserts and makes himself master of its rivers; he breaks up the rising grounds, and spreads them in the form of alluvium over the plains; bores through the Alps and the Andes, and having united the Red Sea with the Mediterranean, is preparing to mingle the waters of the Pacific with those of the West Indian Seas. Nearly all men, being either agents in, or witnesses of, these vast undertakings, allow themselves to be carried away by the fascination of labour, and their only idea is how they can mould the earth into the image which suits them best. And yet, when man forms some loftier ideal as regards his action on the earth, he always perfectly succeeds in improving its surface, although he allows the scenery to retain its natural beauty. Nature preserves its beauty when the really intel-

ligent agriculturist gives up raising and forcing, as if at haphazard, plants of the most various kinds, on a soil the properties of which he is ignorant, when, before intrusting to cultivation, he first and foremost comprehends that the land must not be recklessly dealt with, and previously humours it, by finding out the crops best suited for it. Thus, the "Shakers" in the United States, who have made agricultural labour "a ceremony of love," and feel it a duty to cherish the trees which they rear, the seed which they cast into the furrows, and the rivulet which they turn to their purpose, have really succeeded in converting into perfect paradises their estates at Mount Lebanon, Hancock, and Water-Vliet.* England is the country in which the agriculturists produce from their fields the most abundant crops, but yet its people have always shown more respect for trees than was ever the case with the Latin races, and there also we find but few localities which do not possess a certain amount of grace or even of real beauty, owing either to the great oaks standing by themselves and spreading their branches over the meadows, or to the clumps of trees of various kinds dotted about with picturesque art round villages and country houses. The art of man, notwithstanding the opinion of some morose minds, has it in its power to embellish even the aspect of free nature, by giving it the charm of prospect and variety, and above all by placing it in harmony with the deepest-seated feelings of those who inhabit it. In Switzerland, on the shores of the great lakes, and in front of blue mountains and glittering glaciers, how many instances there are, both of farm-houses and villas, which, by their grassy lawns, their clumps of flower-beds, and their shady walks, render the face of nature still more beautiful, and charm as if by some pleasant dream of happiness the traveller who passes by!

At the present time, the freedom from prejudice which science gives, the love of liberty which is spreading far and wide, the feeling of solidarity which often influences us without our knowledge, and teaches us the fact that the earth belongs to all, have singularly enlarged the breadth of view taken by man. At the same time, the increase of travelling is revealing more and more the beauty of the earth and the harmony of its agencies. For a few years past especially, there has been springing up a perfect enthusiasm in the feeling of love with which men, eminent in art and science, regard nature.

* Hepworth Dixon, *New America.*

Travellers spread in swarms over all countries which are easy of access, and remarkable for the beauty of their scenery or for the charm of their climate. Multitudes of painters, sketchers, and photographers are traversing the whole earth, from the banks of the Yang-tse-Kiang to those of the Amazon; they study the land, the sea, and the forests in all their most varied aspects; they exhibit to us all the magnificent scenes on the globe which we inhabit, and in consequence of their being brought more and more into intimate communion with nature, and of the works of art brought back from their innumerable voyages and travels, all men of cultivation can now form an acquaintance with the features and aspect of the different countries of the globe. The class of *savants*, although less numerous than that of the artists, are still more useful in their labours of discovery, and have also become wanderers over the earth, and the whole world now forms their sphere of study; it was while travelling from the Andes to the Altai that Humboldt composed his admirable *Tableaux de la Nature*, dedicated, as he says, "to those who, impelled by the love of liberty, have been able to tear themselves away from the troublesome waves of life."

Henceforth, owing to these travels, the globe itself will become the agent in ennobling the taste of its inhabitants and in communicating to them the sense of the truly beautiful. Those who traverse the Pyrenees, the Alps, or the Himulayas, or even the high cliffs along the sea-shore, those who plunge into the depths of the virgin forest or look down into a volcanic crater, learn, while looking at these magnificent sights, how to appreciate the true beauty of less striking scenery, and when they have the power of modifying it they will not fail to respect its peculiar features. We must therefore wish every success to that noble passion which impels so many men, and, we must add, the best among men, to penetrate into virgin forests, to traverse sea-shores and mountain-gorges, and to examine nature in all the regions of the globe where she has preserved her primitive beauty. It is now felt that, unless we wish to subside into intellectual and moral weakness, it is necessary that the vulgarity of so many ugly and commonplace things, in which narrow-minded people think that they discern the evidences of modern civilization, should be counterbalanced at any cost by the contemplation of the magnificent scenery of the earth. It is necessary that the direct study of nature and the consideration of its phenomena should become one of the principal elements of education for every cultivated

man; it is also necessary that skill and muscular energy should be developed in every individual, so that he may be able cheerfully to scale the highest mountain-peaks and look down into their abysses without fear, and also to keep up in the whole of his physical being that natural balance of power, without which the noblest prospects are surveyed only through a veil, as it were, of sadness and melancholy. The man of modern times ought to combine in his own proper person all the virtues of those who have gone before him on the earth; without surrendering any of the enormous privileges intrusted to him by civilization, it is his duty also to maintain unimpaired all the vigour bequeathed to him, and not to allow himself to be excelled by any savage on the earth in strength, skill, or a knowledge of the phenomena of nature. In the grand times of the old Greek republics, the great object which the Hellenes had in view in the education of their children was to turn them into heroes by means of grace, strength, and courage; and in like manner, by stimulating all manly qualities in the rising generation, by bringing them face to face with nature, and by leaving them to fight out the battle with her, modern societies of men may insure themselves against the occurrence of any decadence by the regeneration of the very race itself.

A robust education of this kind will give us the grandest development of the real love for nature. Slavery and a spirit of routine may vitiate it; but knowledge and liberty give it new life. Science, which is gradually converting the globe into one great organism always at work for the benefit of mankind, doing this by means of winds and currents, steam and the electric fluid, is at the same time pointing out to us the means for beautifying the surface of the earth, and for making it that pleasant garden which has been dreamt of by poets in all ages. Nevertheless, although science may bring before our eyes the distant future of a glorified earth, she alone cannot bring to perfection this great work. A moral progress must necessarily correspond with this progress in knowledge. Whilst men are fighting with one another with the aim of shifting the patrimonial boundaries and the imaginary frontiers of their nations, whilst the soil which nourishes them continues to be reddened with the blood of insensate wretches who wage war either for a paltry strip of territory, or for some question of so-called honour, or incited by a mere lust for conflict, like the barbarians of ancient times, so long will be deferred that paradise on earth which the mind's eye of the seeker already

seems to contemplate in the distant future. The features of the globe will never assume their perfect harmony until men are united in one league of justice and of peace. Ere she can become truly beauteous our "beneficent mother" must wait until her sons have all embraced as brothers, and have succeeded in establishing the grand confederation of free nations.

THE END.

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